rf/microwave instrumentation

Future In Radiated Immunity Testing

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Agenda: Future In Radiated Immunity Testing

- **What Is Radiated Immunity Testing?**
  - Why Is It Needed
  - What Is The Value In Future Products
  - Defining Susceptibility Thresholds
  - Defining Test Criteria
- **What Are The Standards That Are Applicable For RI Testing**
  - IEC61000-4-3, Auto, Military, Aviation
- **Traditional Radiated Immunity Testing**
  - Equipment Requirements
  - Summary Of Test Procedures And Sample Setup
- **Future Radiated Immunity Testing**
  - Testing With Multiple Tones
  - Benefits
- **Compare Traditional To Future Radiated Immunity Testing**
  - Equipment Requirements
  - Calibration
  - Testing
  - Reporting
- **Summary Of Future Electronic Trends And The Need For Simultaneous Multiple Tone Radiated Immunity Testing**
- **Questions And Answers**

What Do The Following Items Have In Common?

They All Require Radiated Immunity Testing.

Why Is Radiated Immunity Testing Needed

Everywhere You Turn, Electronic Devices Are Being Designed To Make Our Lives Easier, Healthier, Faster, Etc…

The Radio Frequency (RF) Spectrum Is Becoming More And More Congested

All Of These Devices Need To Work And Co-exist With Radio Transmitters Of Many Kinds

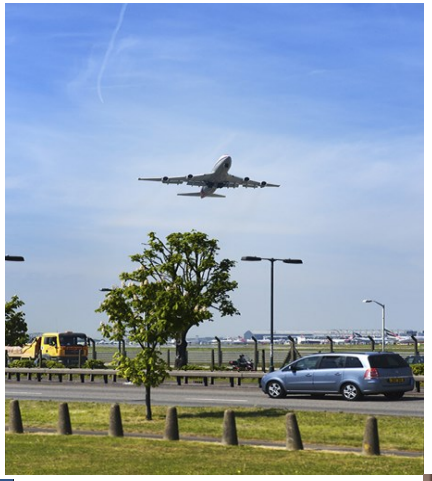
- Products And Systems Must Be Able To Operate In Their Electromagnetic Environment
- They Must Not Introduce Intolerable Electromagnetic Disturbances Back Into The Environment Or Produce Harmonics That Interfere With Other Devices

Manufacturers Must Anticipate The Most Likely Environment That Their Product Will Be Used In

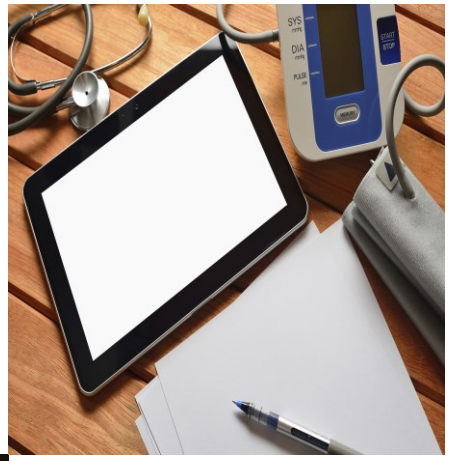
That's Where Radiated Immunity Testing Comes In

Examples Of Electronic Products Co-existing

Car Driving Next To Airport



Medical Instrument With A Cell Phone Next To It



Power Wind Mill With Radar System In Proximity

Microwave Oven With A Cell Phone

What Happens When You Have RF Interference

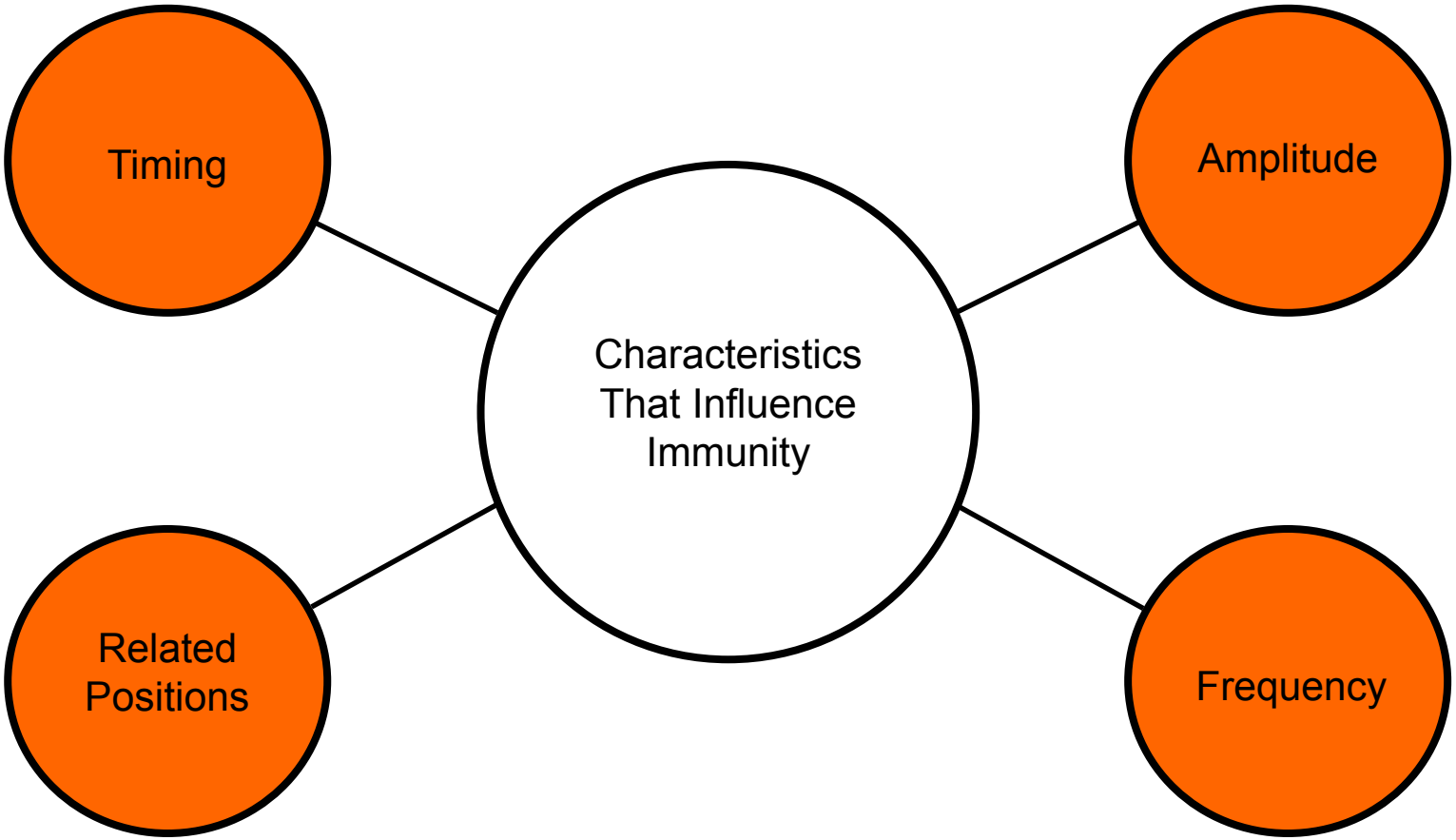
Critical Electronic Devices Might Fail

What Is The Value Of Radiated Immunity Testing Today And Tomorrow - Priceless!

What Is Radiated Immunity Testing

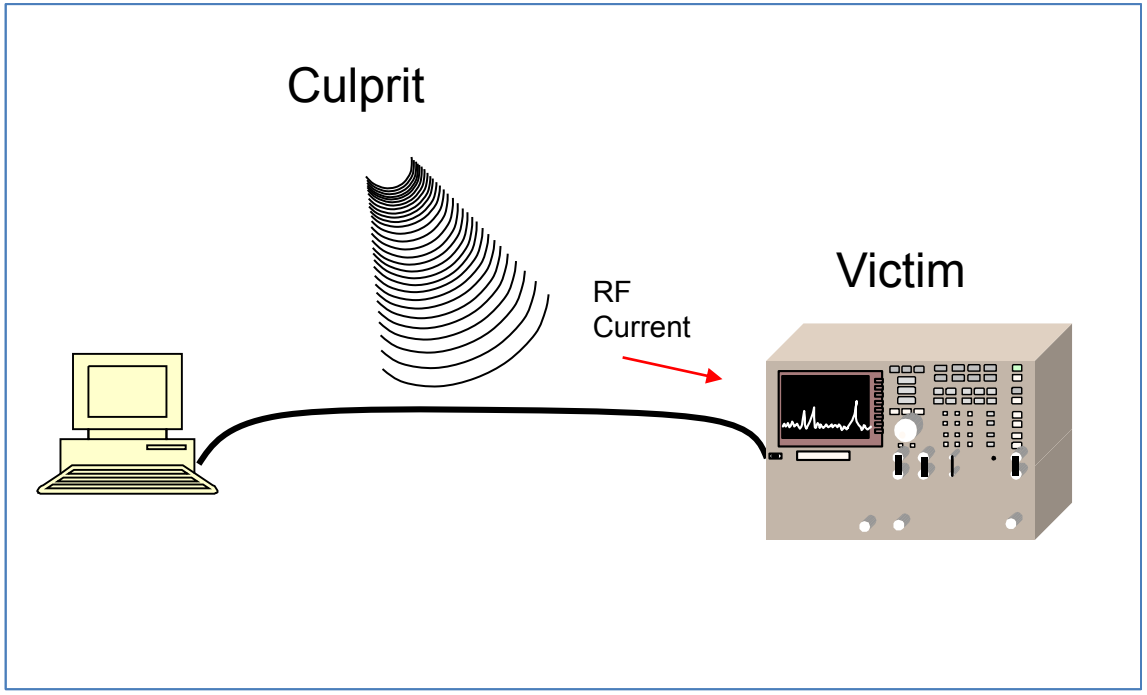
- Before A Product Or System Hits The Marketplace, It Must Be Tested For RF Immunity And Emissions
- Immunity (Also Called Susceptibility) Is A Measure Of The Ability Of Electronic Products To Tolerate The Influence Of Electrical Energy (Radiated Or Conducted) From Other Electronic Products And Electromagnetic Phenomena
- The Test Methods Are Divided Into Application Of Stress By Conducted Coupling, And By Radiated Field Coupling

Characteristics That Influence Immunity Testing

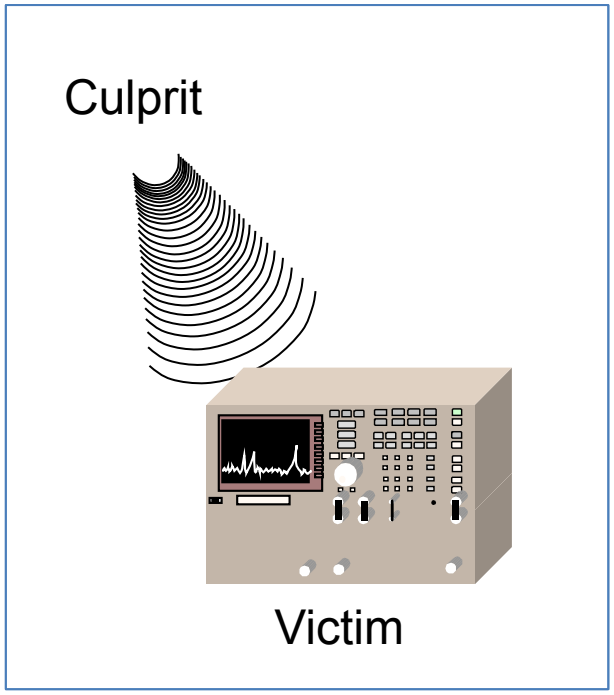


Characteristics That Influence Immunity Testing Frequency

Out-Of-Band



In-Band



Defining Radiated Immunity Test Criteria

To Perform An Immunity Test, The Manufacturer Defines Performance Criteria Against Which A Product Will Be Assessed. These Are Commonly Divided Into Three Categories During An Immunity Test:

- The Product Continues To Operate As Intended
- Degradation Of The Product Performance Occurs, But Normal Operation Resumes At The End Of The Test With No Data Loss
- The Product Either Stops Functioning Or Its Performance Degrades And Does Not Recover After The Test Without Intervention

Whenever Performing Immunity Testing, It Is Very Important That:

- The Performance Criteria And The Monitoring Method Be Clearly Defined
- The Product Is Operating In A Fully Exercised Mode, Allowing For The Easy Observance Of Failures
- An **Objective** Set Of Metrics Is Used (Such As Bit Error Rate, SINAD) **Rather Than** A **Subjective** Metric (Watch For The LED To Stop Flashing, Observe Monitor Screen For Distortion, Etc.)

Determine If The Interference Occurs Continuously, Periodic Or Randomly

Applicable Radiated Immunity Standards

- IEC 61000-4-3 and Associated Standards
- Substitution Method DO-160
- Automotive Substitution Method (ISO 11452 Or 11451)
- Medical Equipment IEC 60601-1-2
- **These Only Apply To Multiple Tones There Are More Radiated Immunity Specs**

Traditional Radiated Immunity Testing – Equipment Requirements

Power Amplifiers

RF Signal Generators

Horn And Log-periodic Antennas

Directional Coupler

RF Power Meter

Anechoic Chamber

Isotropic Field Probe And Monitor

EMI Filters

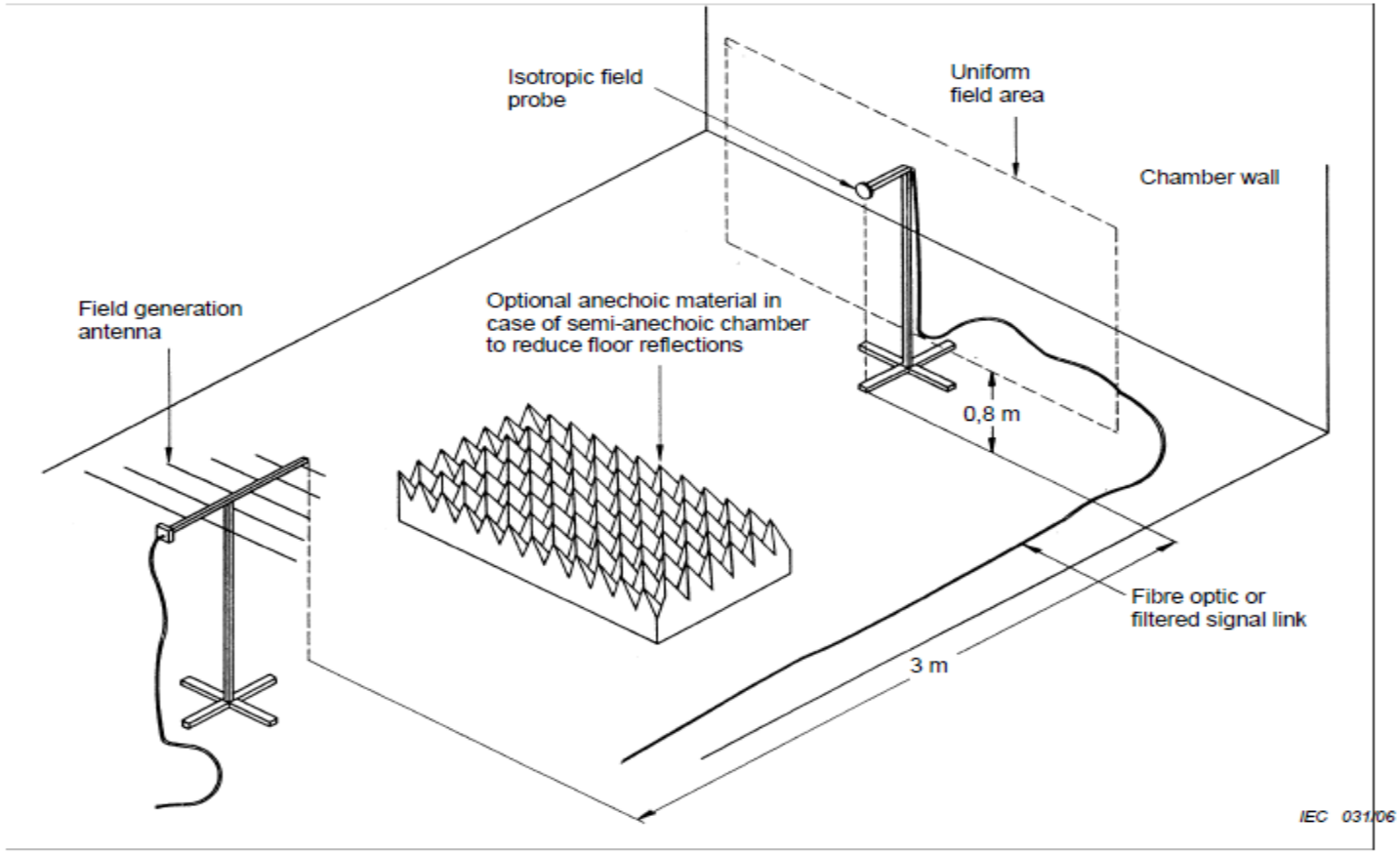
Traditional Radiated Immunity Testing – Summary Of Set-Up And Procedures

Calibration

Test

Report

Radiated Immunity Calibration Set-up



Radiated Immunity Calibration Procedure

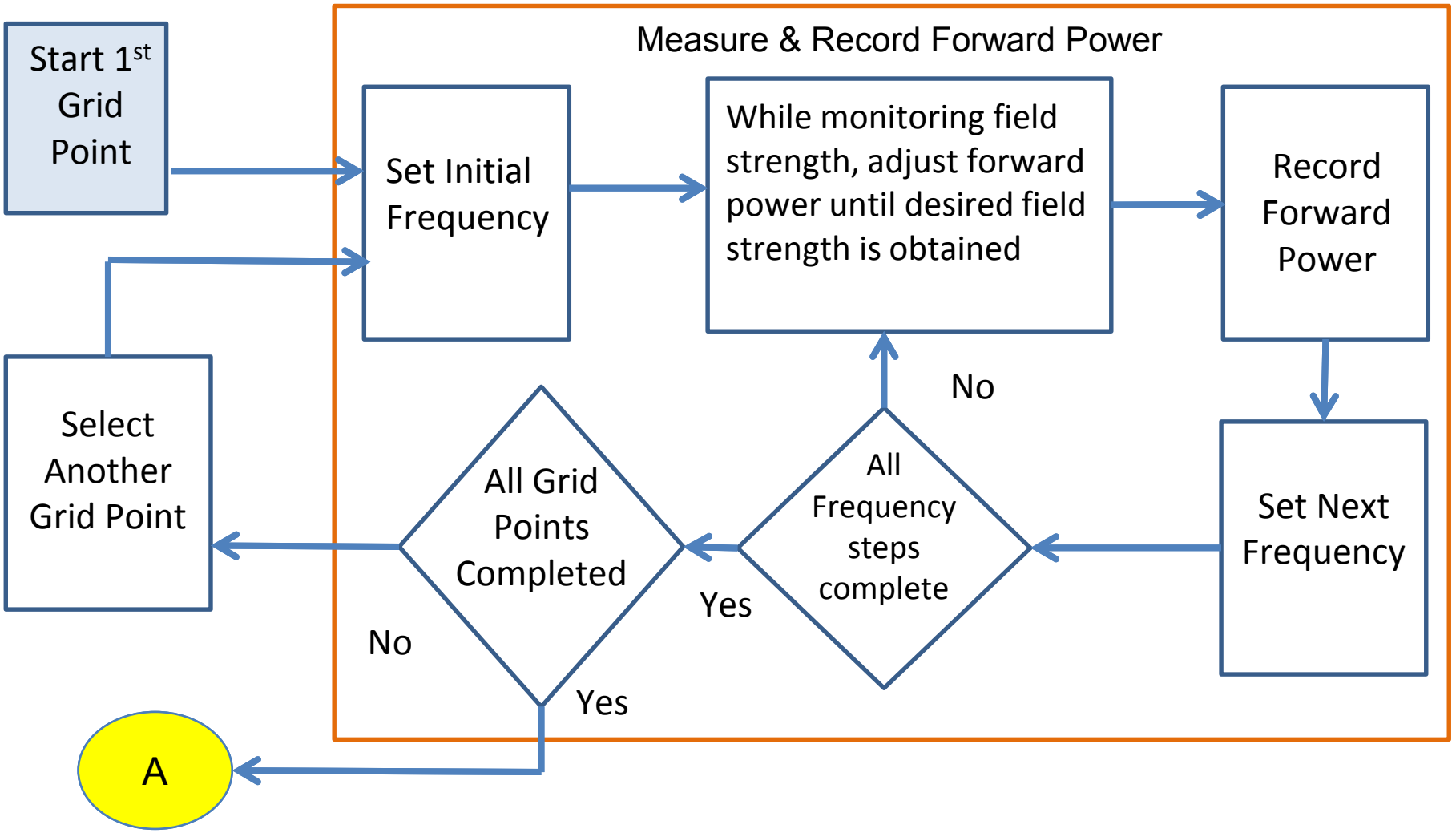
UFA (Uniformity Field Area)

- Constant Field
- Constant Power

Amplifier Not In Saturation

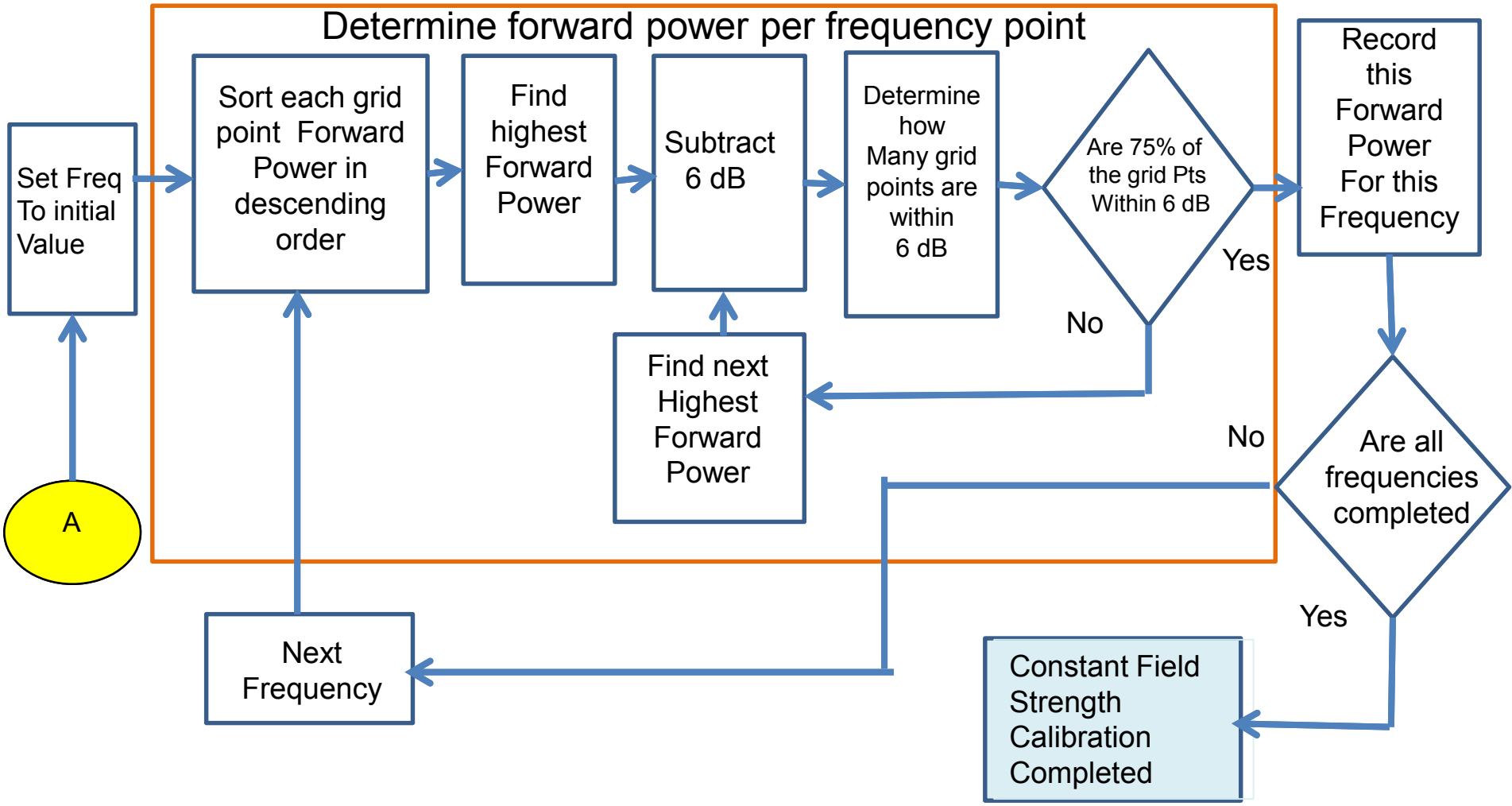
- Linearity
- Intermod And Harmonics

Constant Field Method - Data Collection



Constant Field Method

Determine Forward Power to be Used for Each Frequency Point



Example Of How Field Uniformity Is Calculated Using Constant Field Method and a 16-point Grid

Table #1

Measured Forward Power @ 10 V/m @ 80 MHz

Grid Point (Px)	Forward Power (dBm)
1	27
2	31
3	23
4	26
5	34
6	40
7	33
8	24
9	30
10	28
11	35
12	37
13	25
14	31
15	22
16	29

Table #2

Arrange Forward Power in descending order
To determine 75 % points within 6 dB

Grid Point (Px)	Forward Power (dBm)	Range 1 40 and *34 (dBm)	Range 2 37 and *31 (dBm)	Range 3 35 and *29 (dBm)
6	40	40		
12	37	37	37	
11	35	35	35	35
5	34	34	34	34
7	34	34	34	34
2	33		33	33
14	32		32	32
9	31		31	31
16	31		31	31
10	30			30
1	30			30
4	30			30
13	29			29
8	29			29
3	23			
15	22			
		*40 -6 dB =34	*37 -6 dB =31	*35 -6 dB =29

Points within 6 dB in %

31.25% (5 out of 16)

50% (8 out of 16)

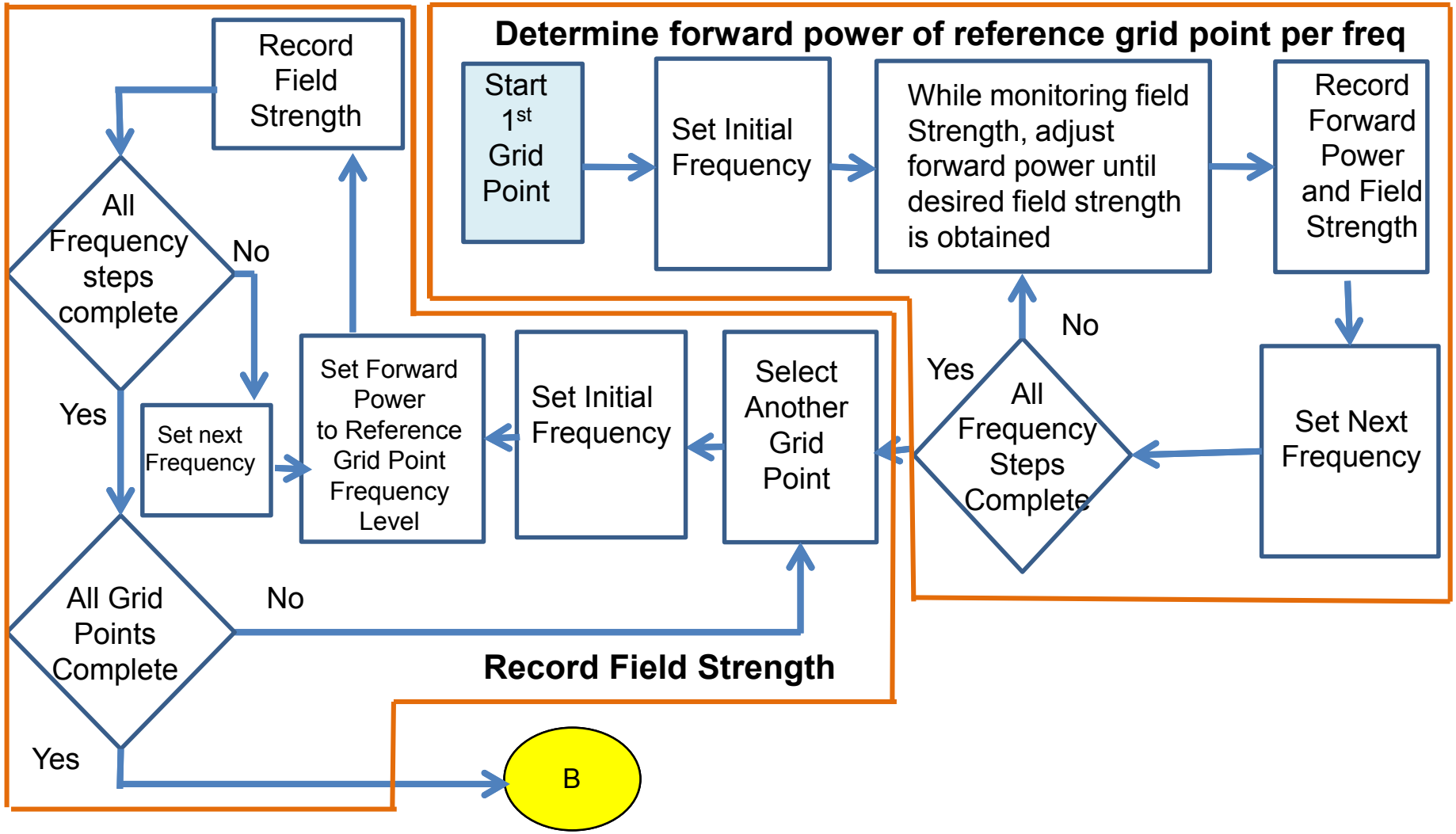
75% (12 out of 16)

Highlighted cells show grid points within 6 dB window

Conclusion: Use Forward Power of 35 dBm from position 11

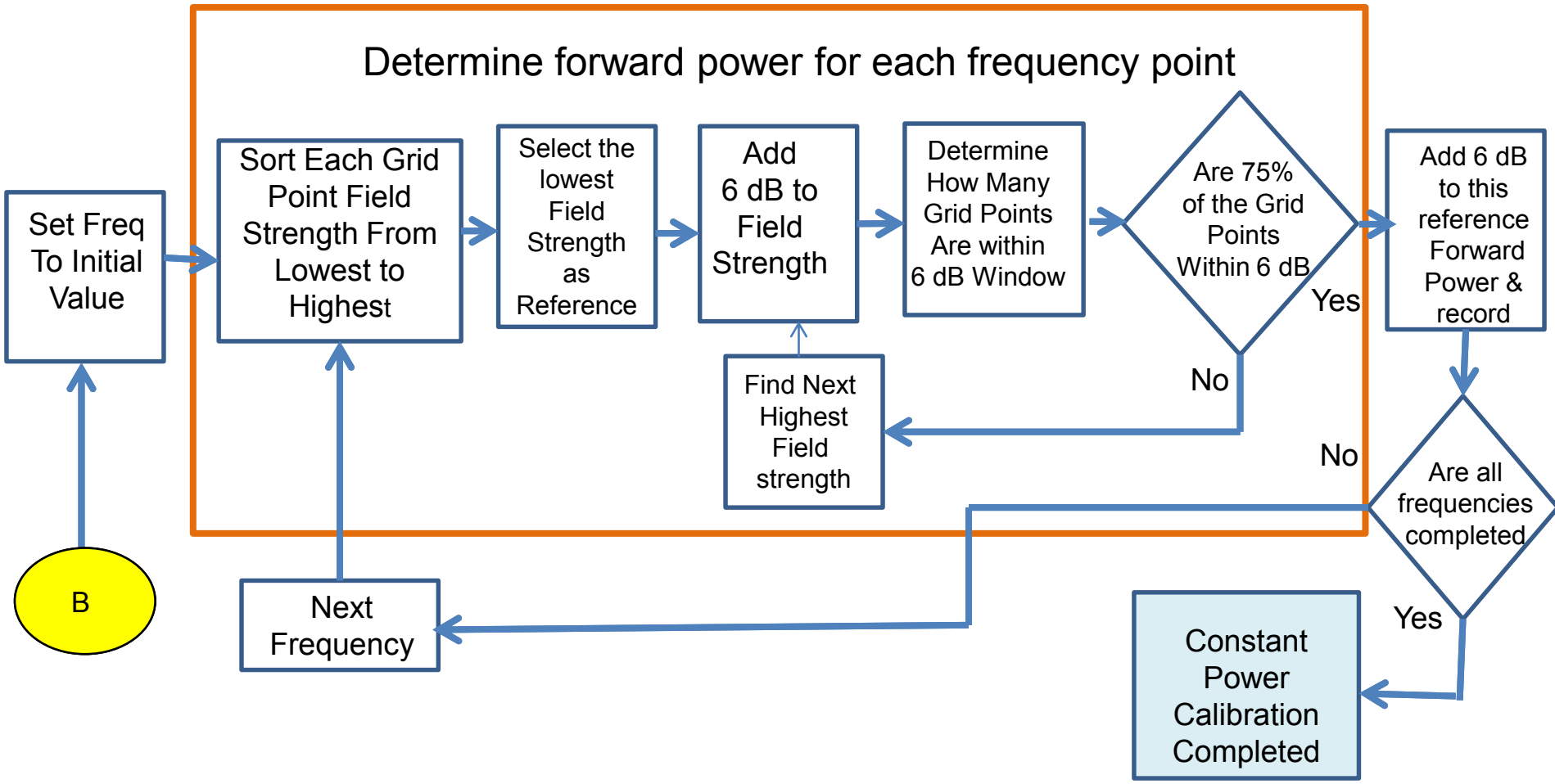
Constant Power Method Part 1 of 2

Measure and Record Field Strength



Constant Power Method Part 2 of 2

Determine Forward Power for Each Frequency Point



Example Of How Field Uniformity Is Calculated

Using Constant Power Method Using A 16 Point Grid

Table #1

Measured Field Strength
Based on 10 V/m @ 80 MHz

Grid Point (Px)	Forward Power (dBm)	Field Strength V/m	Field Strength Related to position 1 (V/m)
1	29	10	0
2	29	14	4
3	29	9	-1
4	29	9	-1
5	29	10	0
6	29	8	-2
7	29	7	-3
8	29	7	-3
9	29	4	-6
10	29	5	-5
11	29	6	-4
12	29	6	-4
13	29	3	-7
14	29	5	-5
15	29	2	-8
16	29	2	-8

Table #2

Field Strength in ascending order
To determine 75 % points within -6 dB

Grid Point (Px)	Forward Power (dBm)	Field Strength V/m	Field Strength Related to position 1 Range 1 -8 to -2(V/m)	Field Strength Related to position 1 Range 2 -7 to -1(V/m)	Field Strength Related to position 1 Range 3 -6 to 0 (V/m)
15	29	2	-8	-8	-8
16	29	2	-8	-8	-8
13	29	3	-7	-7	-7
9	29	4	-6	-6	-6
10	29	5	-5	-5	-5
14	29	5	-5	-5	-5
11	29	6	-4	-4	-4
12	29	6	-4	-4	-4
8	29	7	-3	-3	-3
7	29	7	-3	-3	-3
6	29	8	-2	-2	-2
3	29	8	-1	-1	-1
4	29	9	-1	-1	-1
5	29	10	-1	0	0
1	29	10	0	0	0
2	29	14	4	4	4
			-8 + 6 dB = -2	-7 + 6 dB = -1	-6 + 6 dB = 0

Points within -6 dB in %

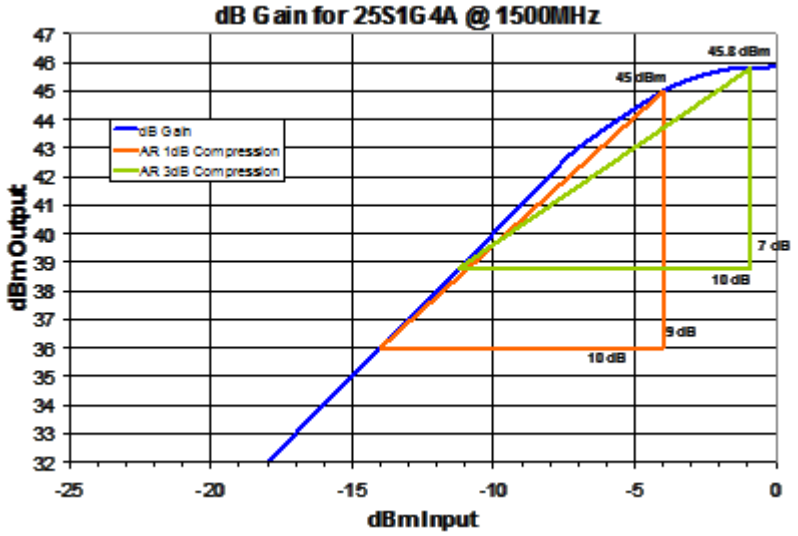
68.75 %
(11 out of 16)

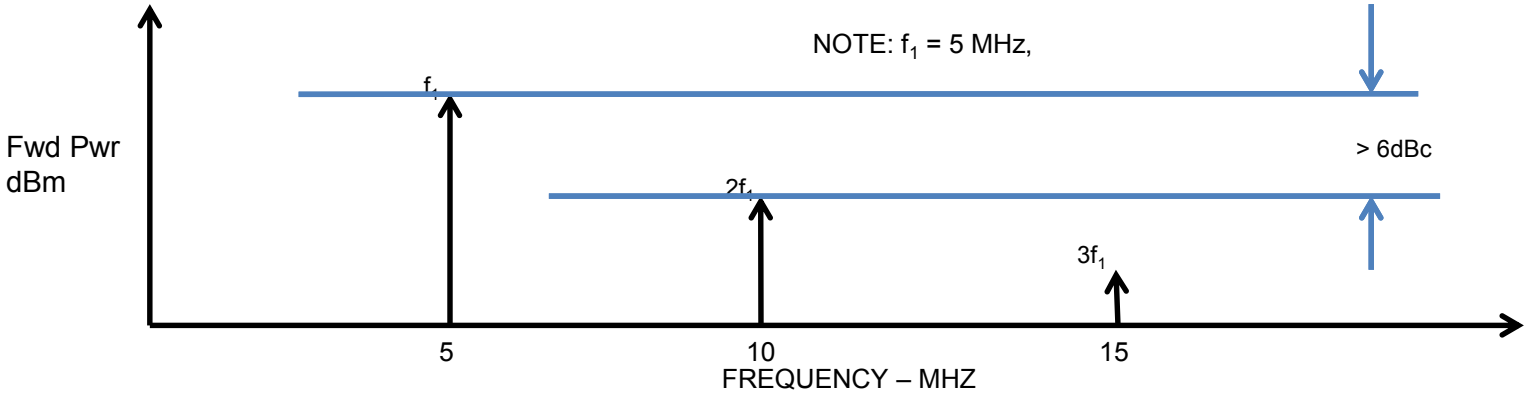
68.75%
(11 out of 16)

75%
(12 out of 16)

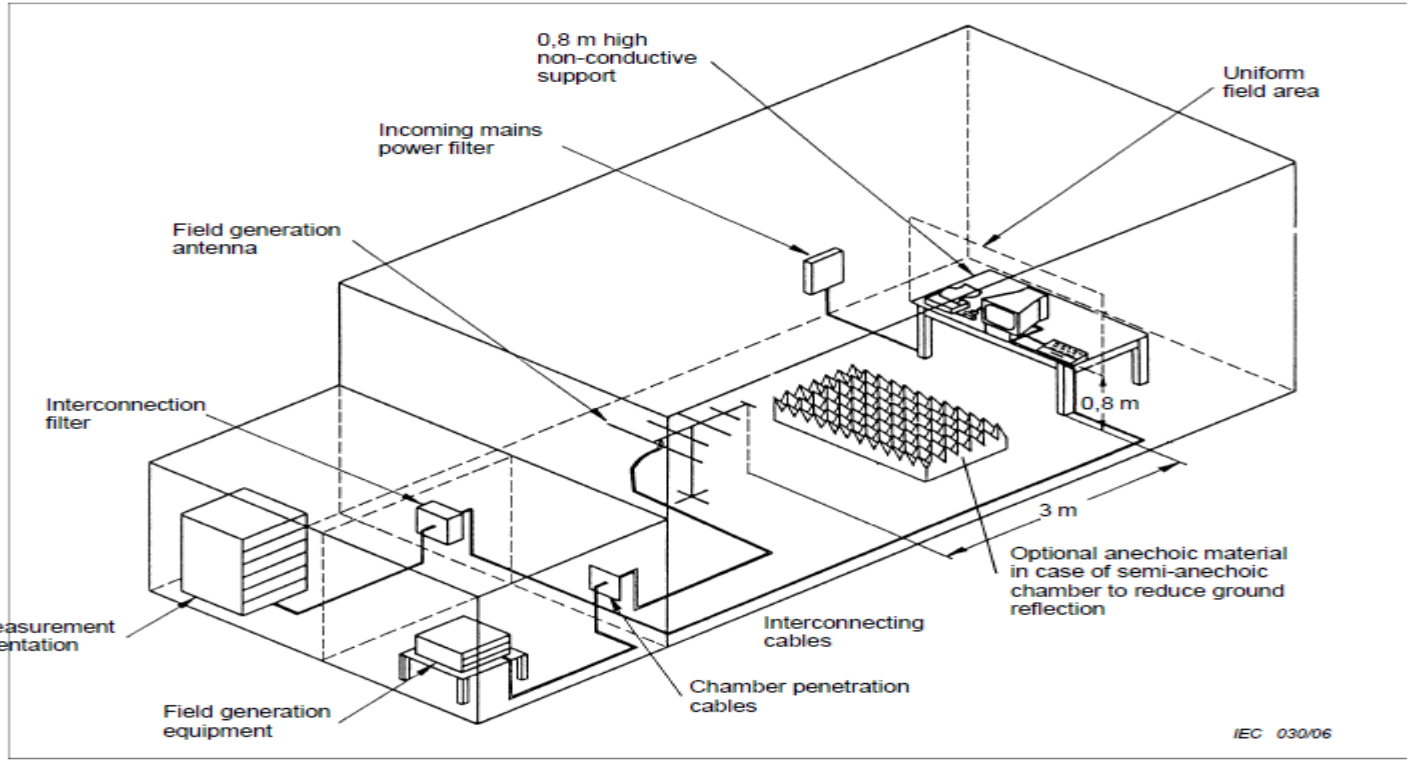
Conclusion: Use Forward Power of **35 dBm** (29 dBm + 6 dB = 35 dBm)

Radiated Immunity Calibration Procedures Linearity and Harmonics





Radiated Immunity Test Set-Up Table-Top And Control Room



NOTE Anechoic lining material on walls and ceiling has been omitted for clarity.

Figure 2 – Example of suitable test facility

Traditional Radiated Immunity Test Procedure

Test

- Level
- Apply Modulation
- Dwell
- Threshold
- Step To Next Frequency And Repeat
- Repeat For All Sides

Traditional Radiated Immunity Test Reporting

Test Reports Should Contain All The Information Necessary To Reproduce The Test Such As:

- EUT And Test Equipment Identification Including Brand Name, Product Type And Serial Number
- Any Special Environmental Conditions
- Defined Performance Level
- Performance Criterion And Rationale For The Pass/Fail
- Any Observed Disturbances And Their Duration That Affected The EUT During Or After The Test
- A Description Of The Cabling And Equipment Position And Orientation

Multi Tone Radiated Immunity Testing

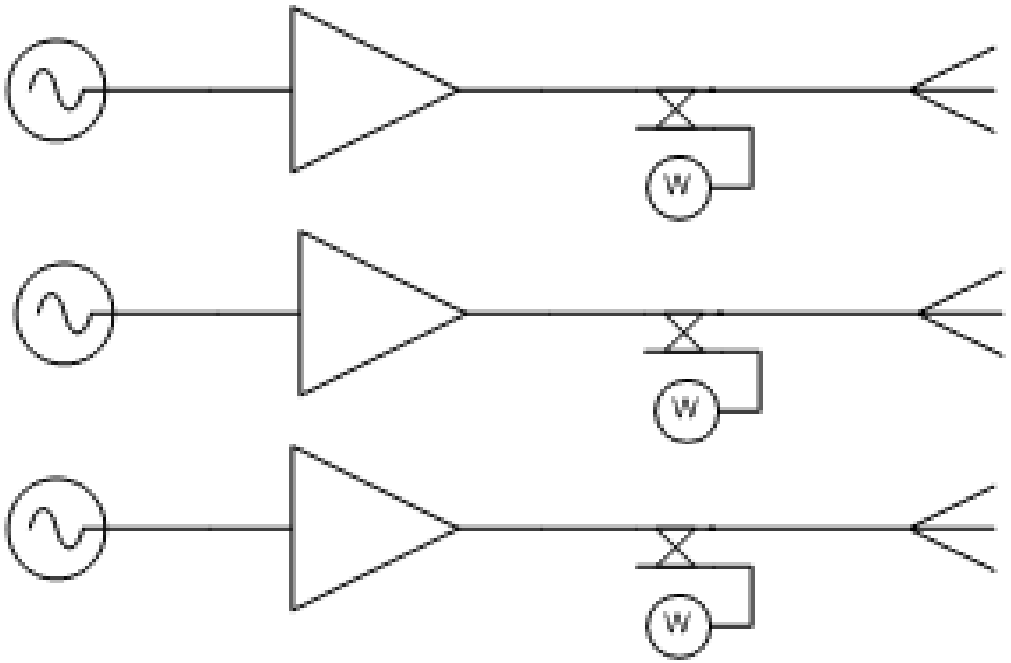
This Section Will Cover Multi Tone Testing

- How To Implement Multi Tone
- Multi Tone Equipment
- Multi Tone Test Setup
- Multi Tone Procedure
- Benefits Of Multi Tone Testing
- Calibration Of Multi Tone

The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing Method 1

How Can This Be Implemented?

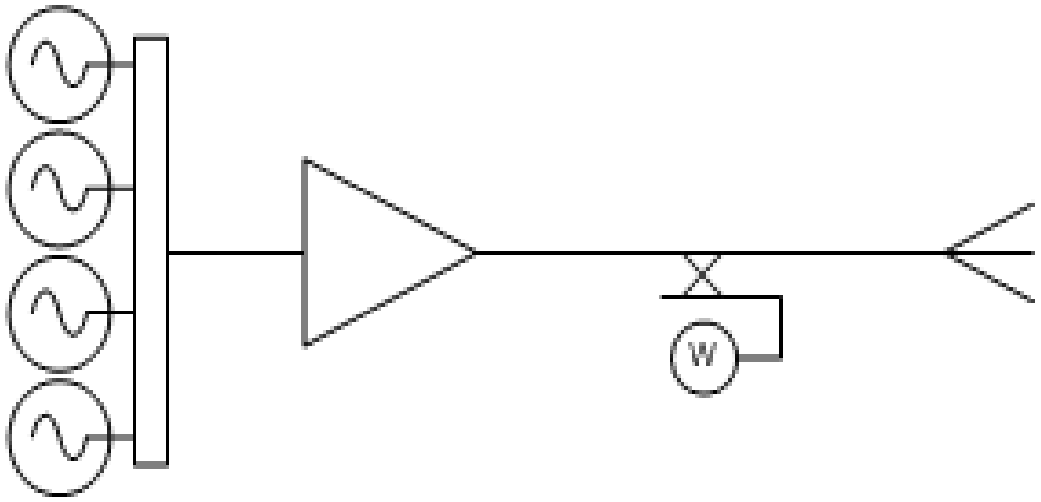
Start With 2 Or More Complete Setups To Radiate The EUT At One Time



The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing Method 2

How Can This Be Implemented?

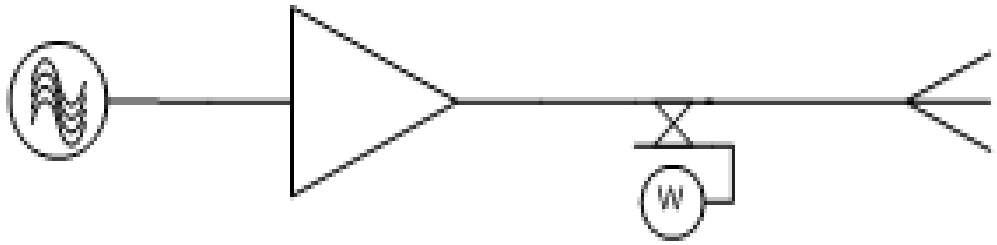
- Simplify The Setup
- Use Multiple Signal Sources To Drive One Amplifier And One Antenna



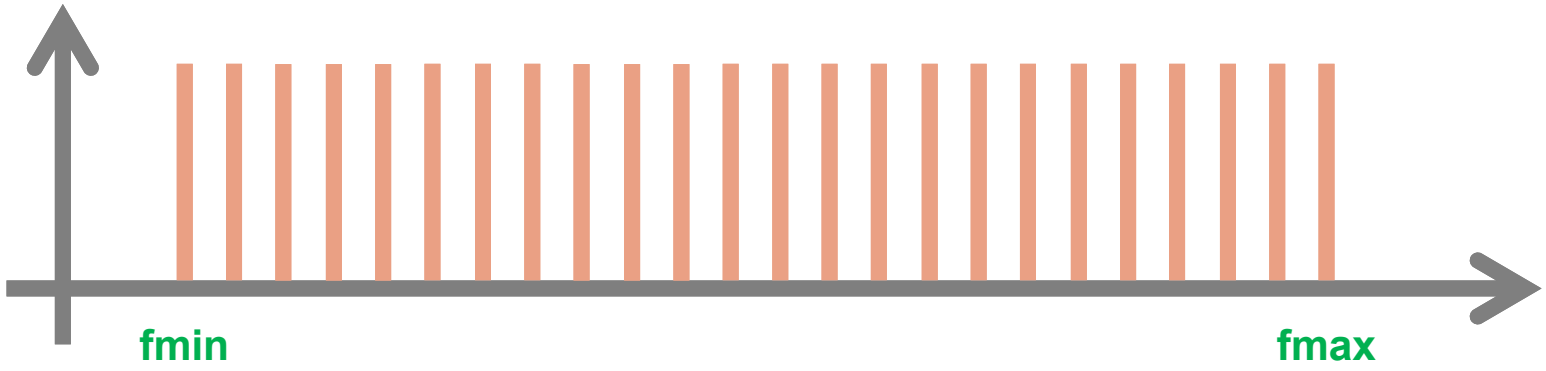
The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing Method 3

How Can This Be Implemented?

- Simplify The Setup
- Use A Vector Signal Generator (VSG) To Generate Multiple Frequencies



Standard “Single-Tone” Test Animation

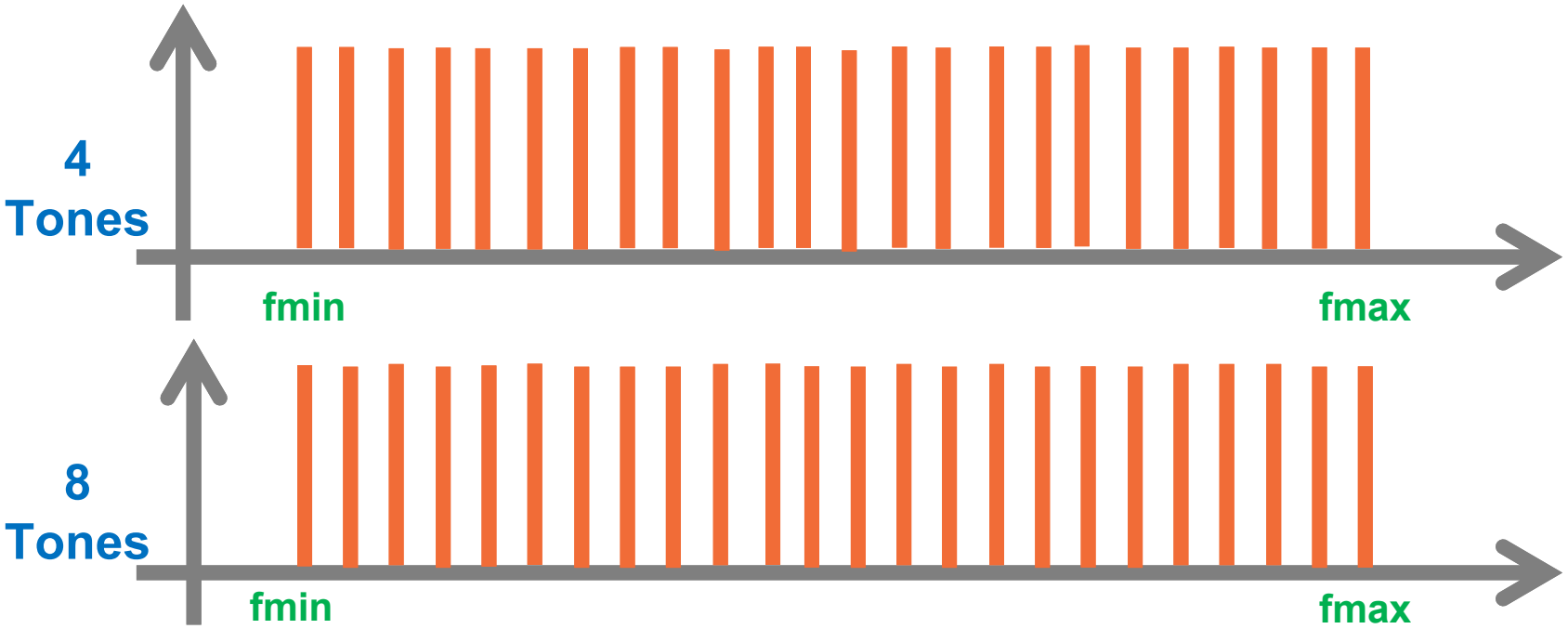


* the frequency range from 80 - 1000 MHz, there are 492 1% steps
* a test setup with 2 antenna polarities and 4 EUT sides has 3936 total steps

(**492** steps x **2** antenna polarities x **4** EUT sides = **3936** steps)

Selected Dwell Time	3 sec	5 sec	10 sec	30 sec	1 min	3 min	5 min
Test Time Required	3.28 h	5.47 h	10.9 h	32.8 h	66 h	197 h	328 h

Multiple Tone Test Animation

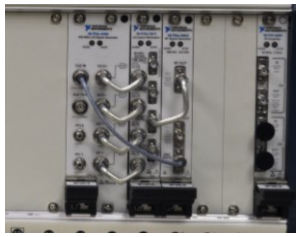


# of Simultaneous Tones	Selected Dwell Time ------>	3 sec	5 sec	10 sec	30 sec	1 min	3 min	5 min
1	Total test time required based on number of tones in set	3.28 h	5.47 h	10.9 h	32.8 h	66 h	197 h	328 h
4		0.82 h	1.37 h	2.73 h	8.2 h	16 h	49.2 h	82 h
8		0.41 h	0.68 h	1.36 h	4.1 h	8 h	24.6 h	41 h

* Based on 492 steps, 2 antenna polarity and four sided EUT

Multiple Tone Radiated Immunity Testing – Equipment Requirements

Higher Power Amplifiers



Vector Signal Generators

Horn And Log-periodic Antennas

Directional Couplers

Vector Signal Analyzer

Anechoic Chamber

Isotropic Field Probe And Monitor

EMI Filters

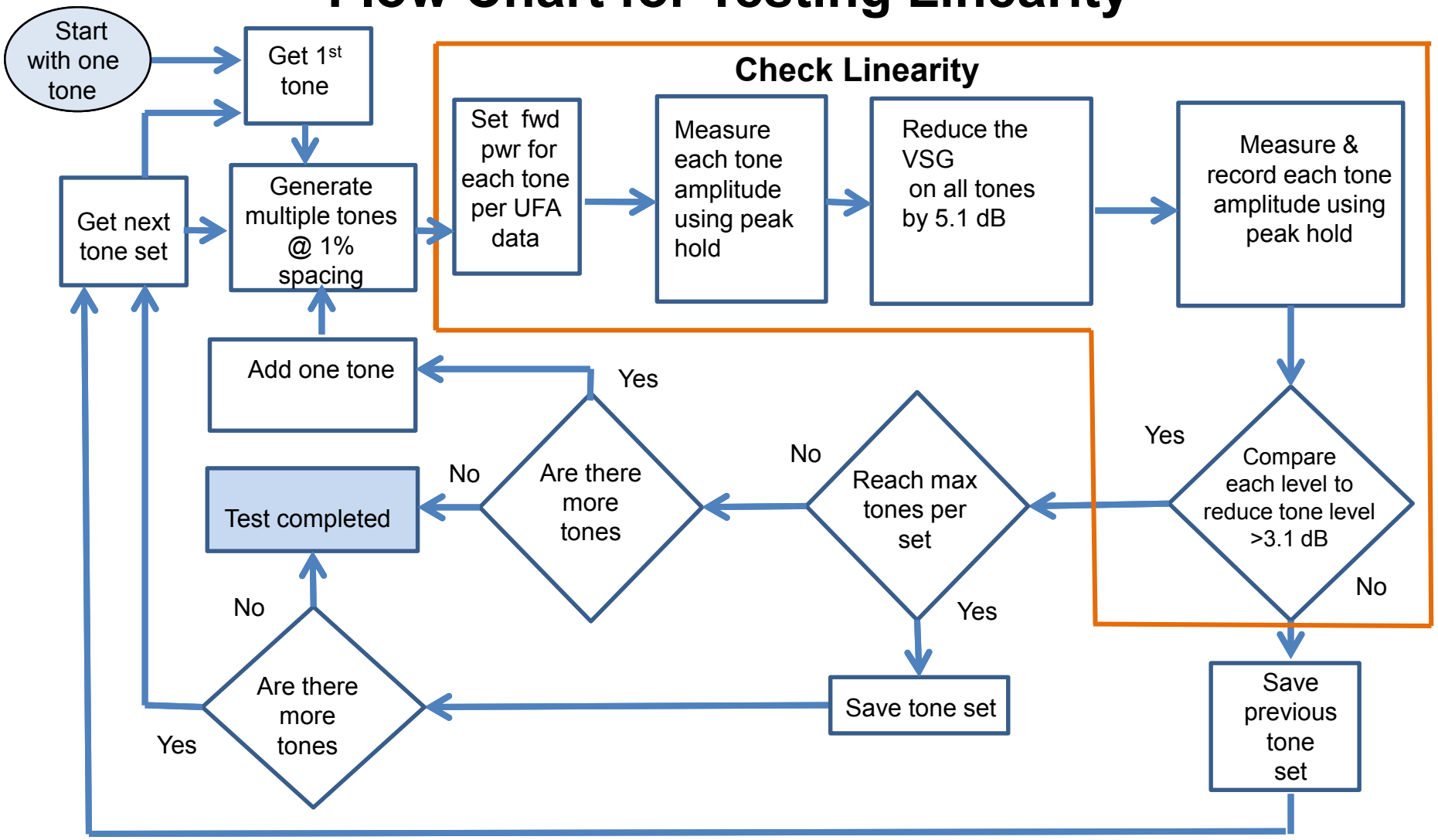
Multiple Tone Radiated Immunity Calibration Test Procedure

UFA (Uniformity Field Area) Calibration Is The Same As Traditional Calibration

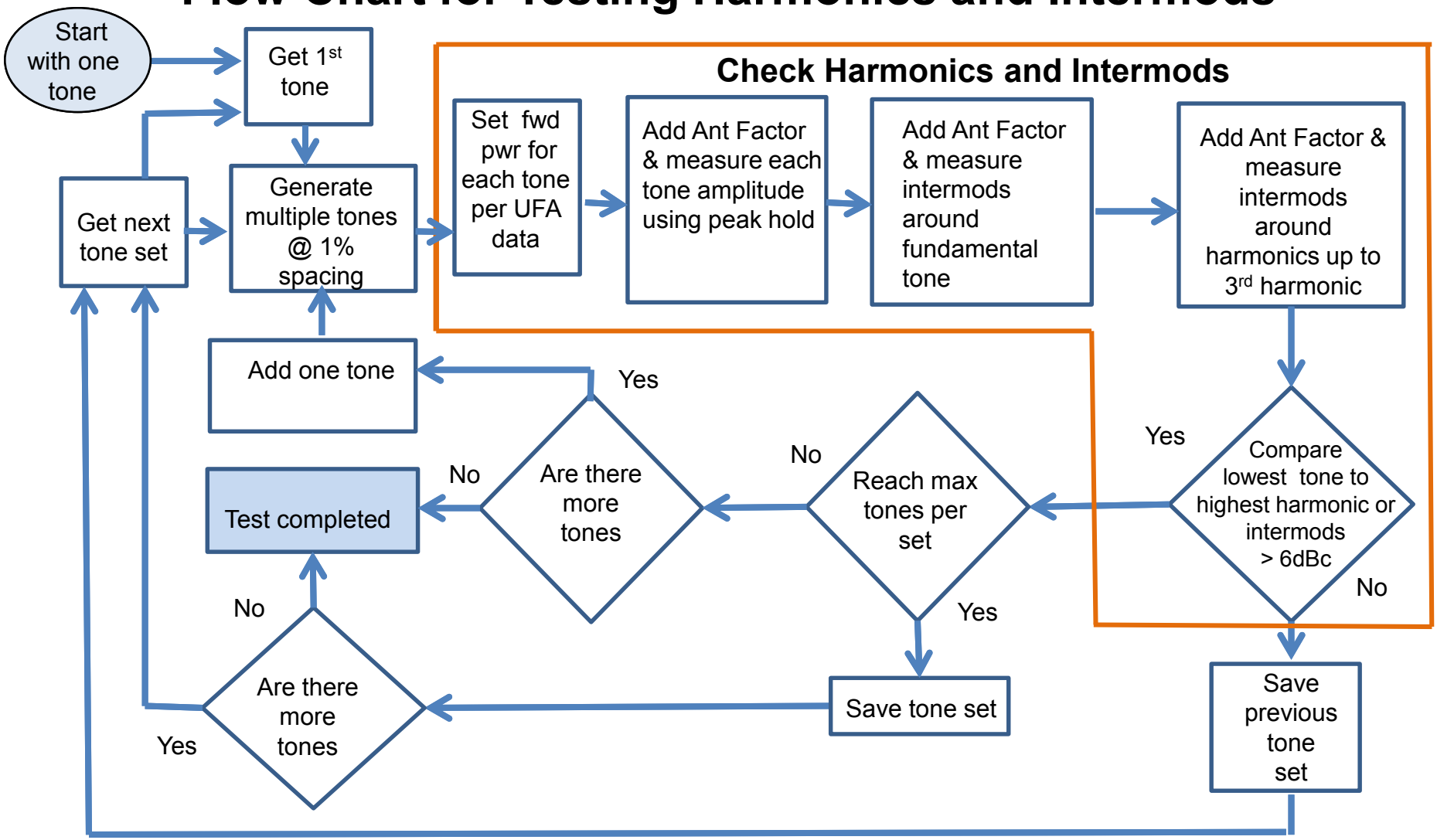
- Constant Field
- Constant Power

Linearity and Harmonics Are Tested To Determine The Grouping Of Tones Used in Each Set

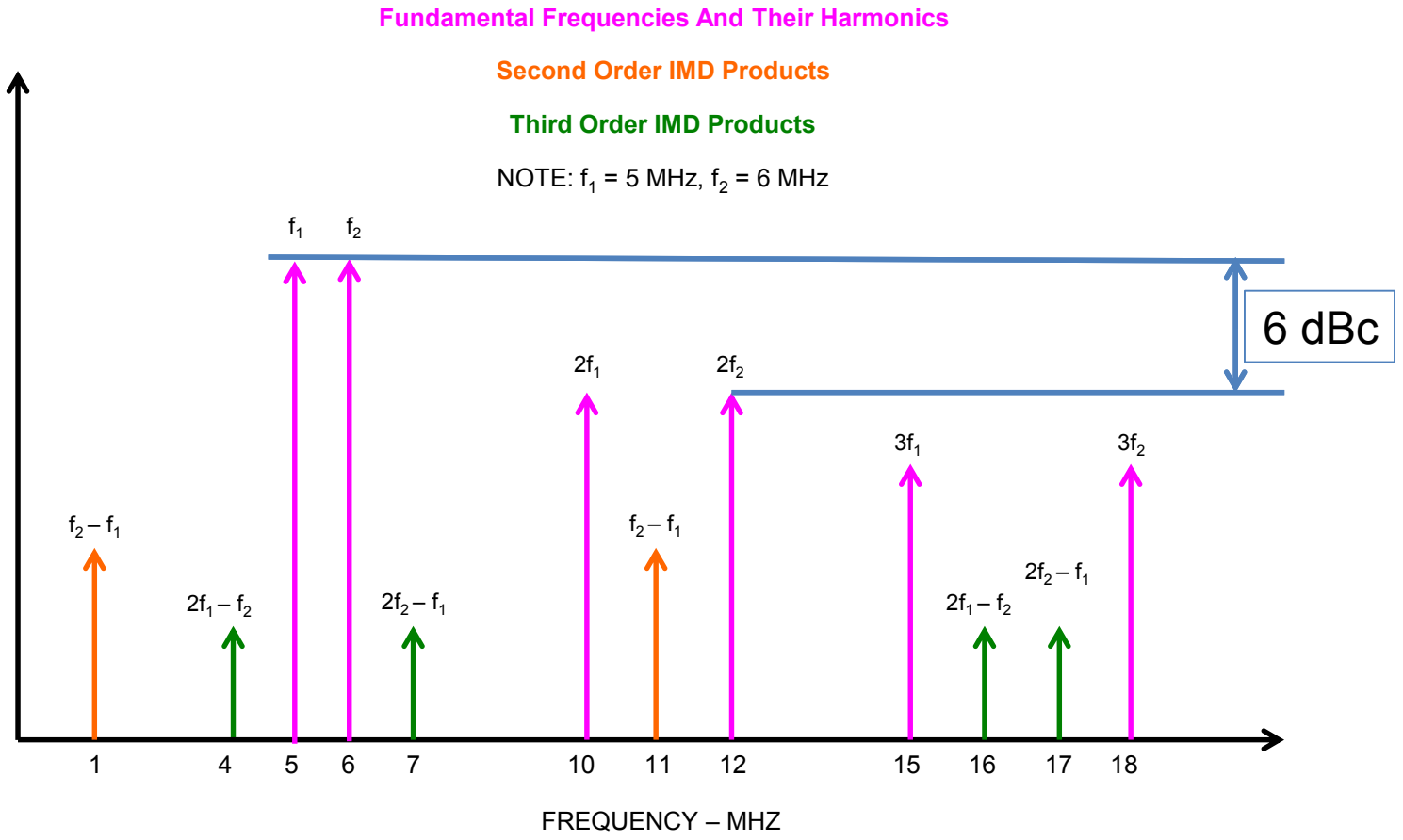
Multiple Tone Radiated Immunity Test Calibration Flow Chart for Testing Linearity



Multiple Tone Radiated Immunity Test Calibration
Flow Chart for Testing Harmonics and Intermods



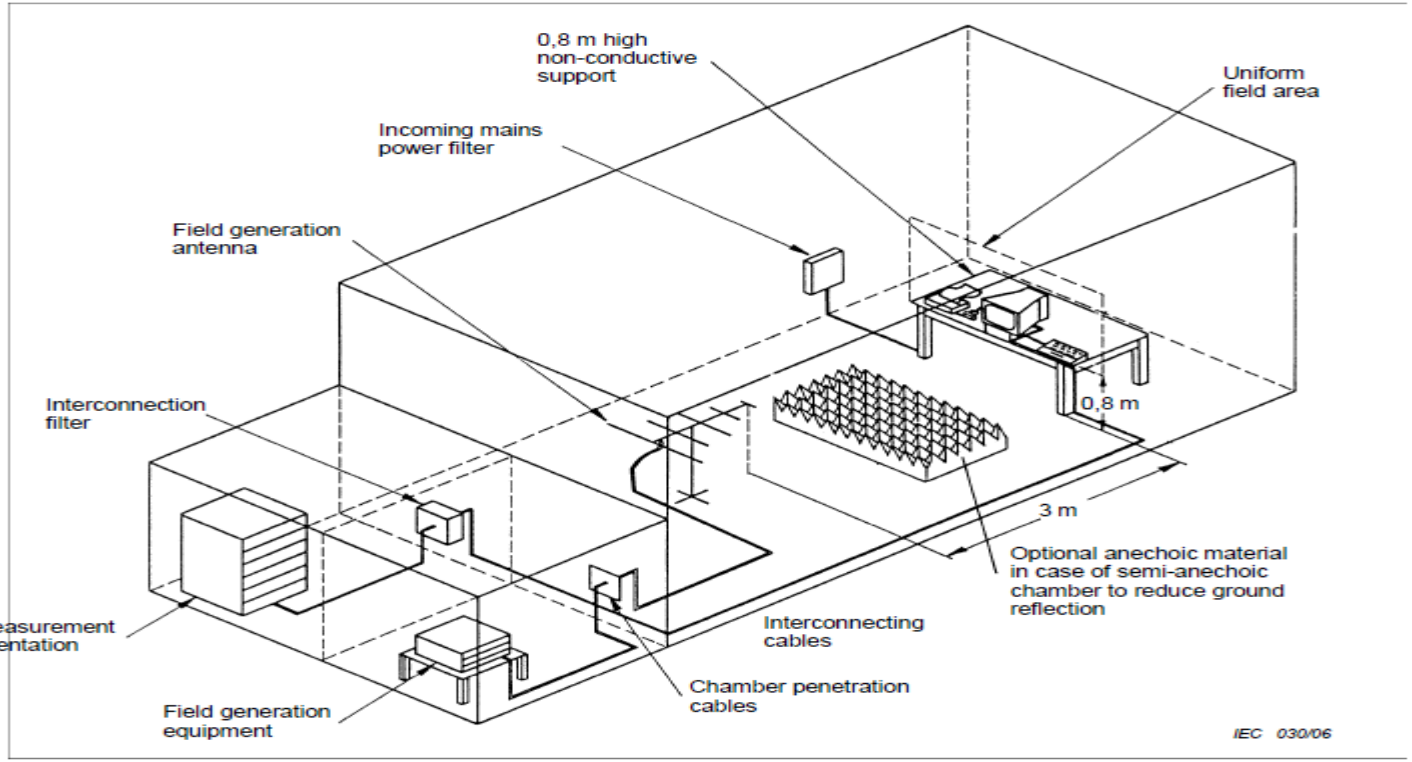
Multiple Tone Radiated Immunity Calibration Harmonics And Intermods (Using Two Tones As An Example)



Number Of Tones Generated Based On 150 MHz BW

Frequency Range (MHz)	# Of Steps In Frequency Range Based On 1% steps	# Of Tones Generated Simultaneously
80 -1000	492	10+
1000-2000	70	10
2000-2500	22	8
2500-3000	19	6
3000-4000	29	5
4000-6000	41	4-2

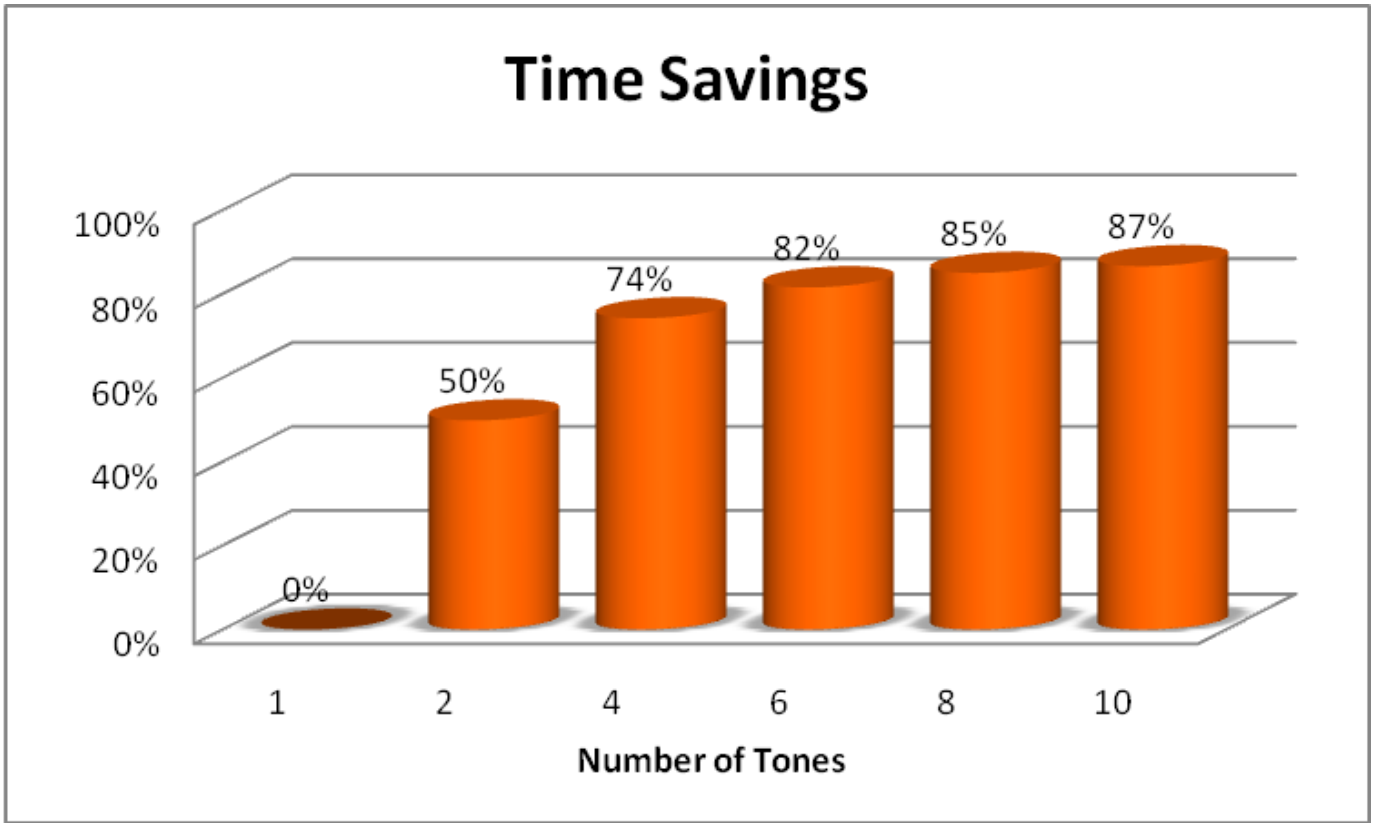
Radiated Immunity Test Set-up
Table-Top And Control Room



NOTE Anechoic lining material on walls and ceiling has been omitted for clarity.

Figure 2 – Example of suitable test facility

Multiple Tone Time Savings



•*IEC 61000-4-3 1% step sizes, taking into account dwell time*

Multiple Tone Radiated Immunity Test & Calibration Reporting

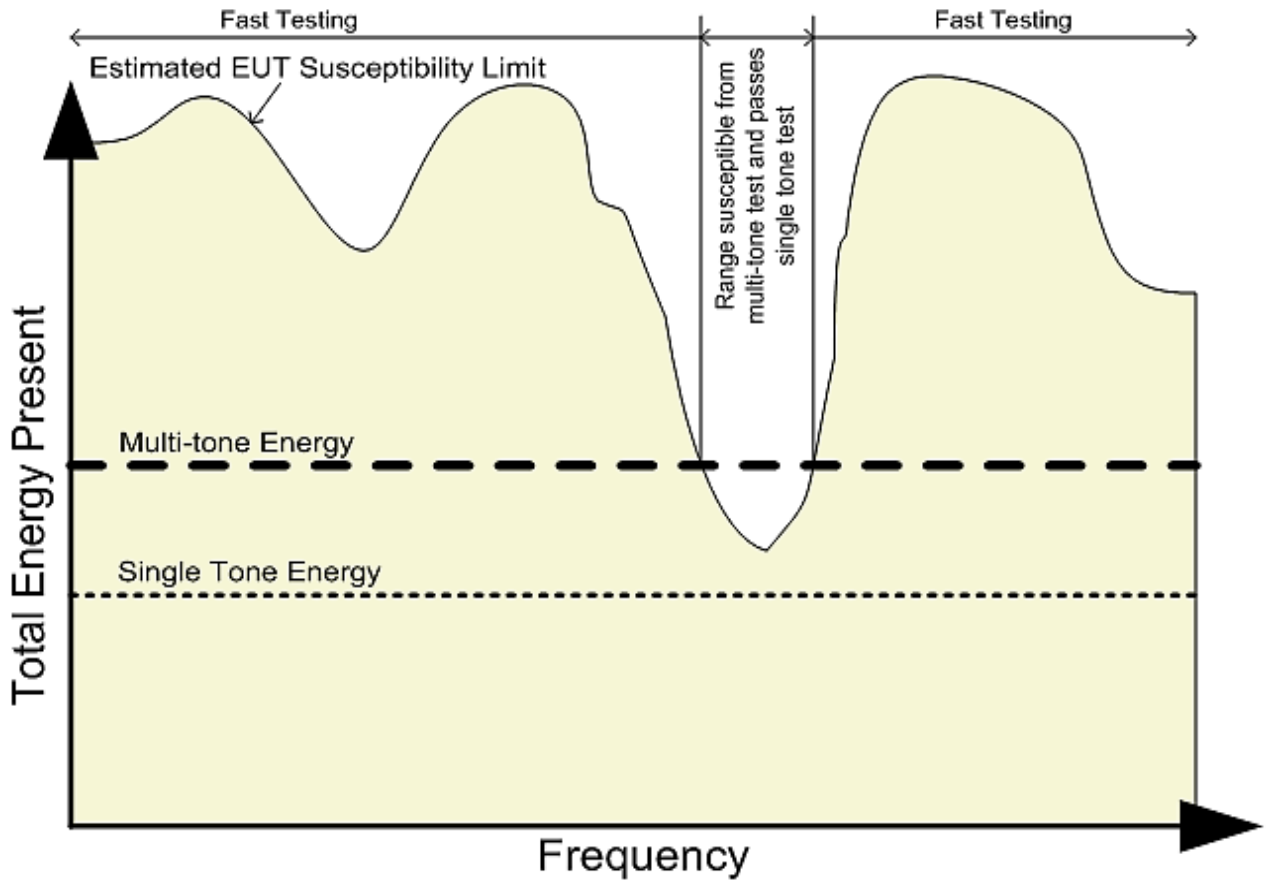
Reporting Requirements Will Functionally Be The Same As The Traditional

The Multi-tone Linearity And Harmonic Calibration Test Will Report:

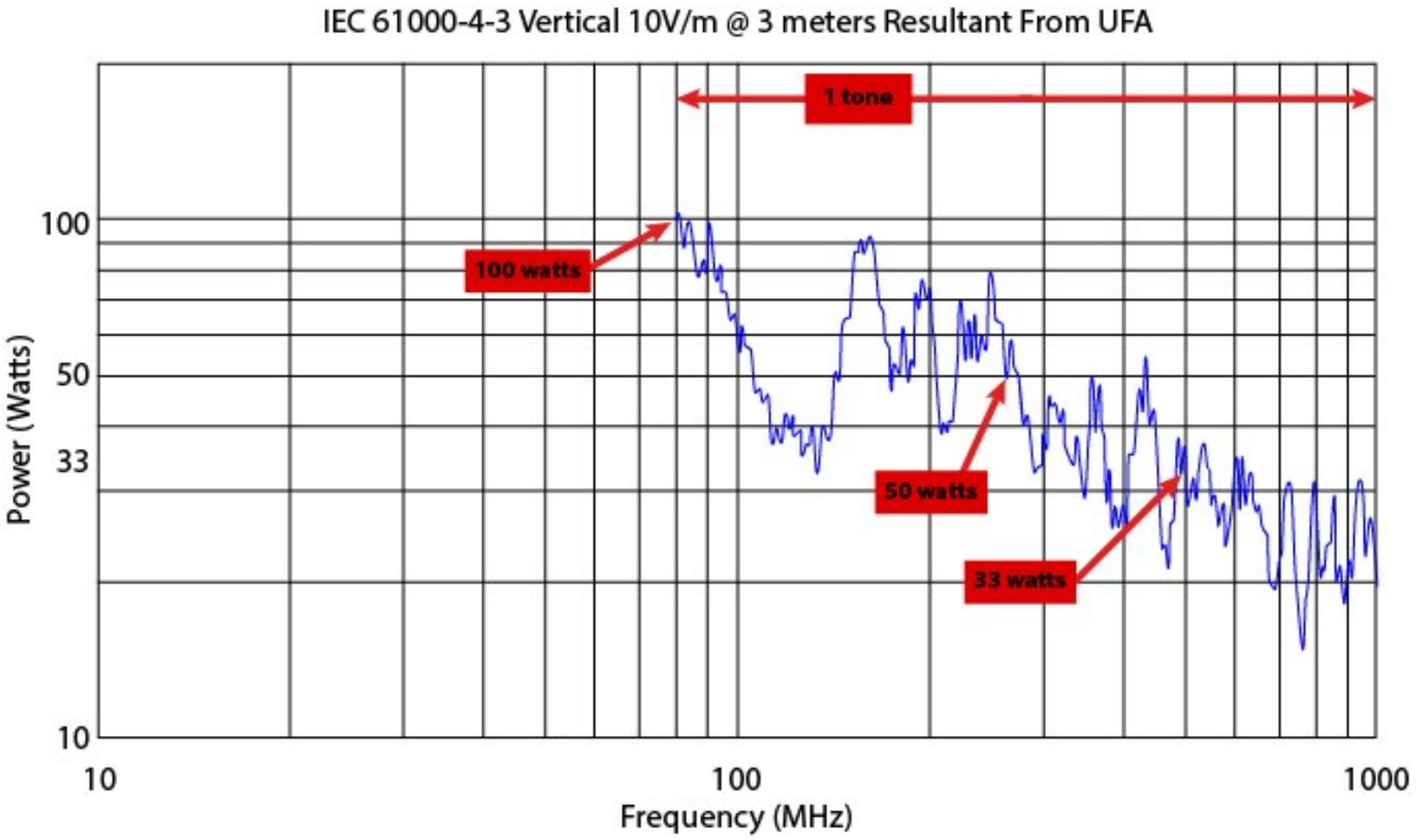
- Linearity For Each Tone
- The Worst Harmonic In Each Set Of Tones

Software Should Provide Necessary Test & Calibration Information To Meet Standard As Well As Document Results In Both Tabular And Graphical Formats.

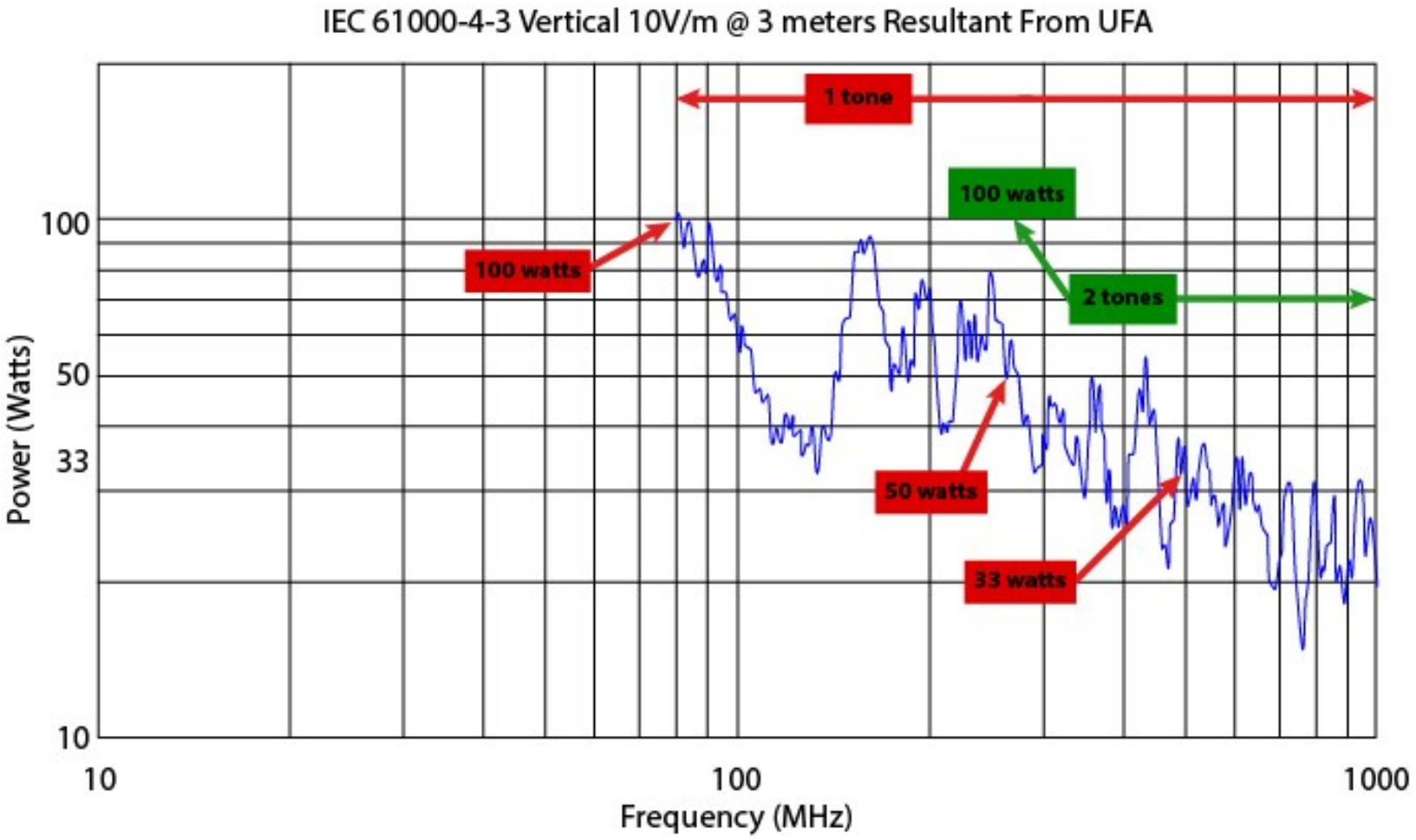
Radiated Immunity Testing Speed



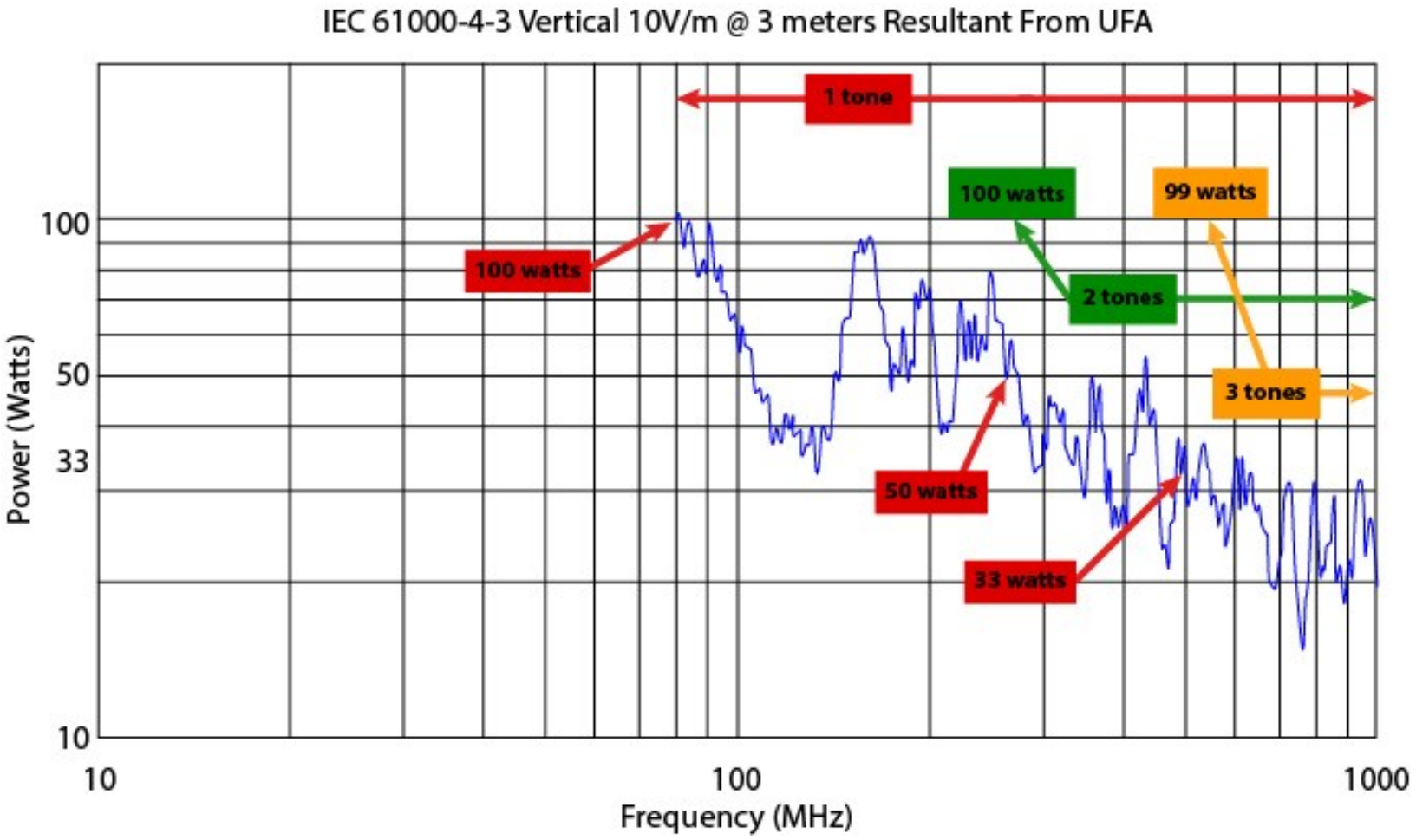
Power Required to Generate 10 V/m



Power Required to Generate 10 V/m



Power Required to Generate 10 V/m



Comparing the Two Radiated Immunity Tests
Where are the differences

	Traditional	Multiple Tones
Required Equipment	Amplifier RF Signal Generator RF Power Meter	Larger Amplifier Vector Signal Generator Vector Signal Analyzer
Calibration Of Linearity, Harmonics And Power Level	Single Tone	Create And Calibrate Tone Groupings/Sets
	Time Savings Is Dependent On Equipment Used. For Example VSG Is Significantly Faster Than GPIB Bus, So Calibration At Group Level Is Faster.	
Testing Procedures		
Performed At	Single Tone	Group Of Tones
Fault Isolation At	Single Tone	Group Then Via Software Down To Single Tone
Given Frequency Range 80-1000 MHz, 492 1% Steps, 2 Antenna Polarities, 4 Sided EUT, 3 Second Dwell Time		
Time Required	2.9 Hrs.	0.43 Hrs.
Associated Time Savings	0%	85%
Reporting	Dependent Upon Software Used, Tabular And Graphical Available	

Recap of the Future of Radiated Testing

- The Future Holds Exponential Growth in the Number of Electronic Devices Required To Coexist
- Radiated Testing is and will continue to be Increasingly Invaluable
- Testing Should Simulate Threats More Close to the Real World Environment
- With Enhanced Saturation of Frequency Ranges, the Potential Exists for Standards Changing To Reflect the Need For More Steps
- Multiple Tone Testing will be Vital To Meet The Dynamics Demands of these Emerging Market Requirements while Reducing Test Time and Improving Overall Testing Efficiencies.

Questions & Answers