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# Communications Interoperability

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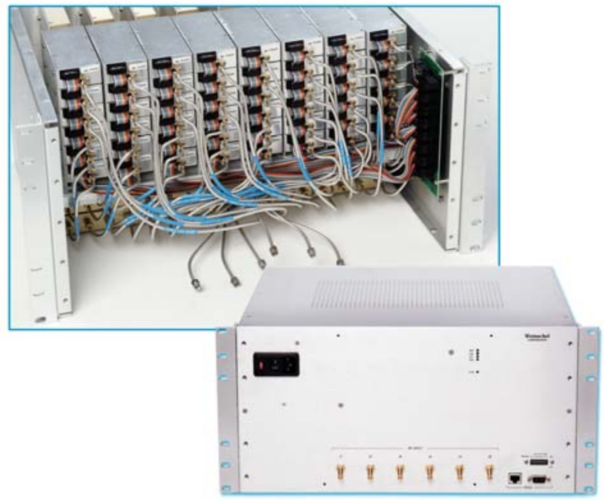

When communication systems are established engineers must account for numerous real world effects and to maintain reliable communication systems.

Information such as:

A) Path Loss – Signal level attenuation from the transmitter to the receiver
B) Immunity to Interference – Calculating and testing the effects of non-intended signals on the intended communications signal or effects of a high density of intended signals.
C) Multi-Path Reflections – Effects of signals reflected off of buildings/structures/mountains
D) Atmosphere Losses – Effects of path losses/reflections of the atmosphere

While real world testing in the exact location of the deployed communication system will yield the best overall information, this is not practical in most cases.

Setting up signal conditions in a controlled laboratory environment allows for many different signal situations and repeatable “Communications Interoperability” test results. This also allows the system engineers the ability to adjust hardware performance parameters to yield high reliability communication systems.

Attenuation Matrix units are used as signal simulation tools to simulate interoperability testing. The signal path loss and channel interaction for multiple communication signals are input into the Attenuation Matrix to simulate real world field conditions in a repeatable, controlled laboratory environment.

Attenuation Matrix testing can be found being used in as many communications situations as can be thought of.  Aeroflex /Weinschel has systems being used for cellular communications (WBCDMA, 3G, UMTS, GSM, Voice, Data, fax , video, interaction between different handset to different base station manufacturers) plus other communication systems.

Attenuation Matrix systems have been deployed into laboratory signal simulation situations to demonstrate:

A) Battlefield Communications
B) Mobile Cell Phone communications
C) 802.11 High Speed train communications
D) 802.11 phone systems
E) Missile Communications
F) Satellite communications
G) Earth to Mars to Earth Communications

All of these communication situations rely on critical RF links. Each of us has encountered dropped cell telephone calls. Annoying, YES, life threatening, not usually. However the service providers take the wrath of customers with dropped calls, seriously. More critical situations include missile navigation/ telemetry links and space satellite / space probe communications. Attenuation matrix test subsystems provide the system engineers realistic communication path/measurement tools to evaluate and solve the problem of “Interoperability.“

Many different block diagram implementations are used to perform these functions.

The structure of these matrix units are all based on a common design platform but can be adjusted to fit specific operational requirements.

There are several different block diagram structures of these types of attenuation matrix units.

The most common design structure is a purely passive non-blocking design. This structure has X inputs into an input power divider, the power divider feeds multiple programmable attenuators which attach to an output power divider and then to Y outputs. The typical design is bi-directional and has significant through path loss due to the dividers. If gain is required then the system will become unidirectional.

This format then provides an X by Y attenuation matrix. See **Figure 1** for a 6 x 2 matrix design.

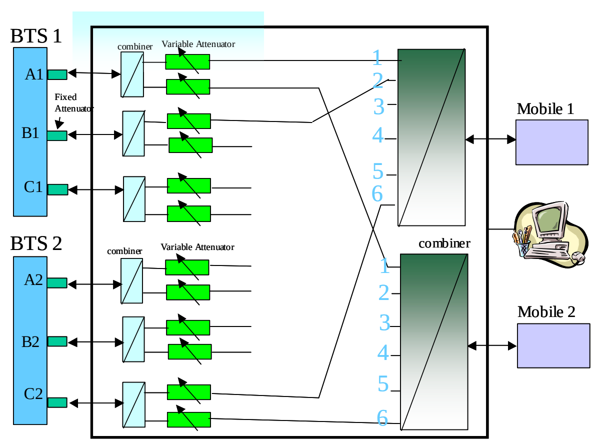


**Figure 1**
**Analog 2x6 Matrix**

During the system engineering evaluation of the Attenuation Matrix selection, the designers must evaluate a few constraints of the test system.

A) X by Y matrix types – A definition of the quantity of inputs vs outputs will define the structure of the matrix.

B) Frequency Range – Typically these test subsystems are designed as having he same input and output frequencies.
C) Bandwidth – The bandwidth of these systems are constrained by the available bandwidth of the power dividers. Usually these can be obtained to cover a few octaves.
D) Input Power Level – This will be determined by the selection of the power level of the power dividers and programmable attenuators.
E) Type of attenuator – Relay, Pin, FET, Phase Compensation
F) Port to Port Isolation- The higher the isolation the more dynamic range that can be achieved through the system. See the next bullet for information.
G) Insertion Loss – The total loss through the dividers and programmable attenuators.
H) Dynamic Range – This parameter may appear to be simple to define but it actually requires a bit of system analysis. Start with the dynamic range of the attenuator. If we use **Figure 2** as a block diagram (8x4 matrix):
I) Phase Change – If necessary specify the maximum phase change during any attenuation change.

These Matrix units can be used in a variety of ways but typically they have transceivers on both inputs and outputs. For interference testing one of the ports is used as a jammer /interferer port to introduce real world noise or interference. The variable attenuators are used to simulate loss of signal due to movement/path loss/distance/ and/or reflections from the transmitter to the receiver. This information is important to the field system designers locating positions of repeater towers used for signal handover. The greater the dynamic range of the test system, the better the information is that can be obtained in determining the field performance of the radios/cell phones under test.

Not all testing requirements are amplitude only testing. Both military and commercial signals have field requirements needing both amplitude and controlled phase testing.

Aeroflex/Weinschel has been able to achieve this capability through the use of our phase compensated programmable attenuators. Most programmable attenuators are accurate amplitude adjustment devices. They are not specified for controlled phase during amplitude adjustment. Therefore as the amplitude changes, phase can be dramatically different for each attenuation step. If this is a system concern it must be initially designed into the test subsystem.

The easy evaluation of the system indicates that the range of the programmable attenuator determines the dynamic range. In this case 0-63 dB. (See **Figure 2)** One of the keys to usage of these systems is that all inputs, are connected to all outputs, at all times. The programmable attenuators adjust the signal levels. However there are "sneak" paths of signals through the system that will limit the system dynamic range.

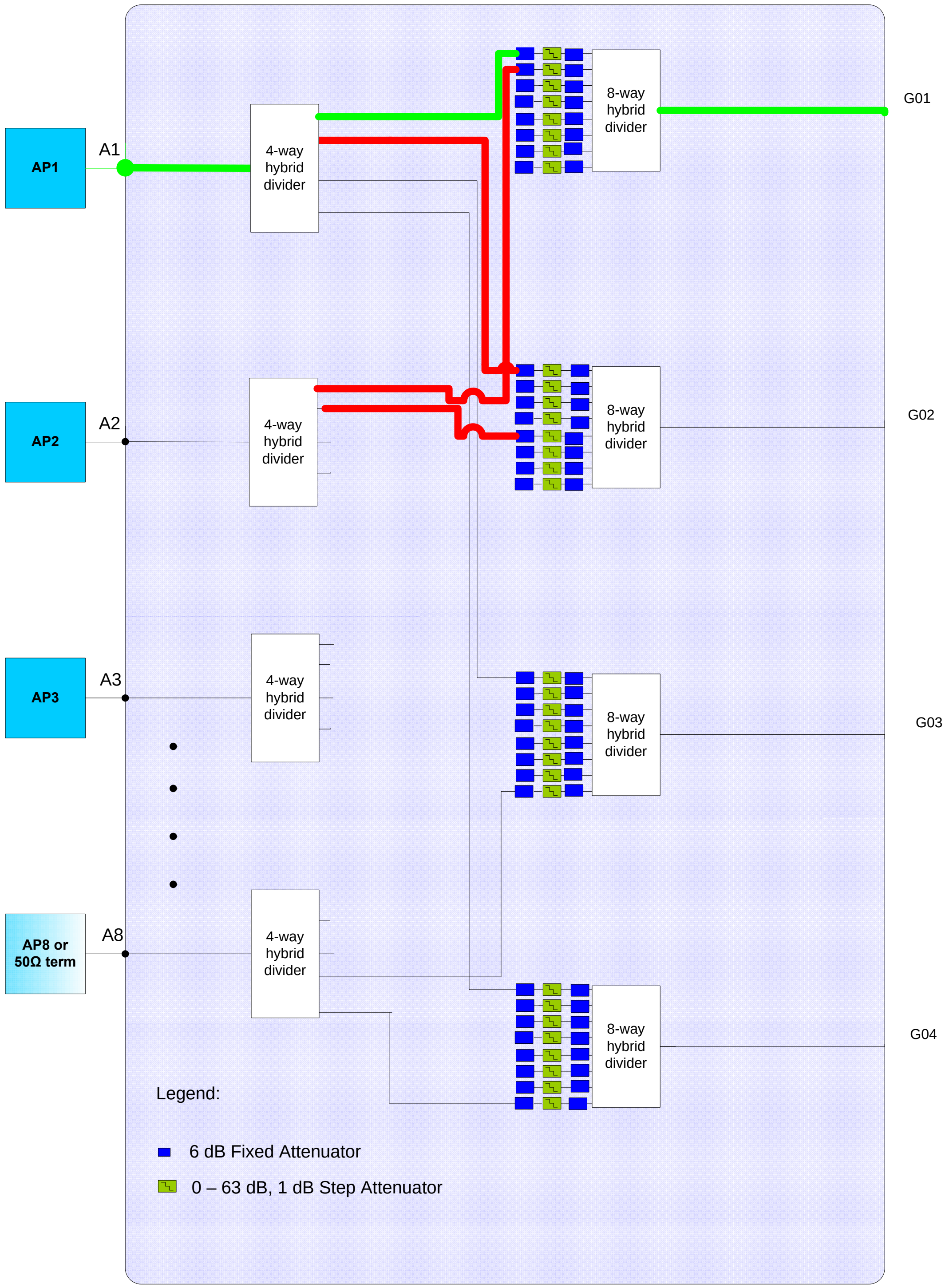


**Figure 2**
**8 x4 Attenuation Matrix**

**Figure 2** is a block diagram for an 8 x 4 attenuation matrix that uses 0-63 dB programmable attenuators. This type of design is limited in dynamic range by the isolation of the input and output dividers. The worst case (limited dynamic range) occurs if one primary path is used and all other paths have 0 dB attenuation selected. Any increase in attenuation level in secondary paths will improve the dynamic range of the primary path.

Lets evaluate the system dynamic range:

Component parameters – insertion loss (dB)

| | |
|---|---|
| 4 way divider | 7 dB (20 dB port to port isolation) |
| 8 way divider | 10 dB (20 dB port to port isolation) |
| 63 dB programmable (0 dB position) | 4 dB |
| Attenuator | 6 dB |
| Cable loss | 2 dB |

The main path loss (selected path) through the system is indicated by the Green line through **Figure 2.**

The calculation is as follows:

4 way divider+ 6 dB attn+ Programmable+ 6 dB attn+ 8 way divider+ cables = Total Insertion loss.

7 dB + 6 dB + 4 dB + 6 dB +10 dB+ 2 dB = 35 dB.

In an ideal situation the system test designer would hope to be able to adjust the matrix output signal from 35 dB of loss to 35 dB + 63 dB = 98 dB of loss.

With the structure of this type of design, since all inputs must always talk to all outputs, unintended paths are always connected. I call these “sneak” paths. (See the RED Path of **Figure 2**.)

Lets calculate the sneak path loss:

4 way divider + cables+ 6 dB attn+ Programmable+ 6 dB attn+ isolation of 8 way divider+ cables + 6 dB attn+ Programmable+ 6 dB attn+ isolation of 4 way divider +6 dB attn+ Programmable+ 6 dB attn+ 8 way divider+ cables = Total Insertion loss.

7 dB+2 dB+6 dB+4 dB+6 dB+20 dB+2 dB+6 dB+4 dB+6 dB+20 dB+6 dB+4 dB+6 dB+10 + 2 dB = 111 dB

So the sneak path loss, through one path = 111 dB.

Now there are 7 sneak paths in this system. The other paths will add further signal leakage and dynamic range degradation. This extra loss in dynamic range is:

10 log (number of sneak paths) = loss in dynamic range
10 log (7) = 8.5 dB

In order to obtain the full system dynamic range the isolation between the sneak paths and the main signal path must be determined.

| | |
|---|---|
| Attenuation Range | 63 dB |
| Sneak Path Leakage<br>10 log (7) | 8.5 dB |
| Margin for < 0.5 dB<br>System measurement error | 10 dB |
| Total required isolation | 81.5 dB |

The sneak path loss minus the main path loss is:

111– 35 =  76 dB.

This shows that there is currently not enough system isolation to obtain the full 63 dB of dynamic range when all secondary paths are set at 0 dB. This system will be limited to approximately 57 dB of dynamic range.

63 dB – (81.5 dB- 76 dB) = 57.5 dB

The range of attenuation control will be 35 dB + 57 dB = 92 dB.

To improve this situation three things can be done.

1) Always operate the system with secondary paths containing as much attenuation as possible.
2) Increase the 6 dB attenuators to add more port to port isolation (however this increases the net system insertion loss)
3) Install dividers with higher port to port isolation (a very difficult thing to do unless a very narrowband system is designed)

Attenuation matrix units of this design configuration offer a very dynamic test platform for evaluating field interoperability issues. By understanding the internal elements and the limitations of the test subsystem a solid set of test data can be obtained to determine "Field Interoperability. "