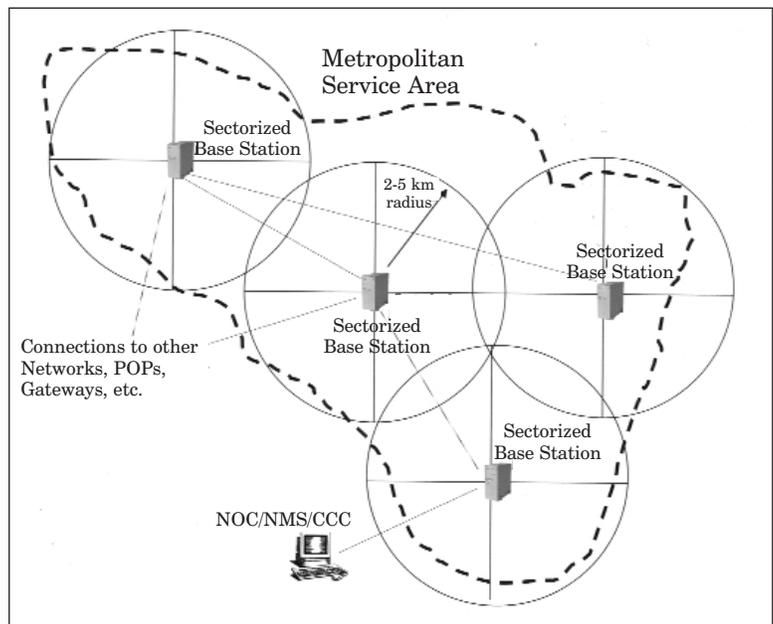


Design and Test Considerations For Multicarrier LMDS Radios

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Recently, a large amount of spectrum has been made available for broadband access applications using fixed wireless access technology broadly known as local multipoint distribution system (LMDS). LMDS network systems typically employ multicell structures realized using sectorized base stations in order to provide service coverage of a given metropolitan service area (Figure 1). The attractiveness of LMDS to the service provider community lies in a variety of areas, including rapid economical coverage of large service areas; high speed, next-generation service delivery; capability to deliver IP, ATM or TDM services from a common network and base station infrastructure; and fast, low-cost deployment of end customer terminals.

Globally, spectrum allocations have been assigned for broadband millimeter-wave access systems. In many cases, the amount of spectrum released is much greater than that available for any other service type. Using these large spectral allocations, the operators are able to deploy systems with very large capacities, often several Gb/s. These large capacities allow the operators to configure multistream service offerings with bandwidths that can compete with other infrastructure options at virtually all bandwidth and service category levels, allowing the networks to serve a broad range of needs ranging from residential to large enterprise.



▲ Figure 1. Typical metropolitan LMDS network deployment concept.

Multicarrier transmitter requirements

When considering broadband license allocations, equipment manufacturers would ideally deploy very large bandwidth, high-speed RF carriers that minimize the overall complexities of the associated base stations. Technology limitations tend to dictate the use of a larger number of narrower bandwidth RF carriers in order to fill out the available spectrum and maximize the operators revenue flow. This larger number of carriers transporting the overall downlinked data load then drives the need for a high performance multi-carrier transmitter that is able to handle a large number of RF carriers without causing distortion.

# of Carriers	Approximate Transmitter Power Needed	Back-off from P _{1dB}
16	29	4
14	28	5
12	28	5
10	26	7
8	26	7
6	25	8
4	23	10
2	20	13
P/carrier (dBm) = 17		OTX P _{1dB} (dBm) = 33

▲ **Table 1. Multicarrier sector transmitter back-offs for various numbers of supported carriers.**

At millimeter wavelengths, there are nominally two approaches to providing the required power levels associated with multicarrier RF transmission. The first, traveling wave tube technology, requires high to very high power, a large number of carriers per transmitter (i.e., 20 to 40 carriers), low reliability and high cost per sector. This method is also difficult to engineer for outdoor use and results in large prime power consumption and challenging back-up requirements. Conversely, solid state transmitter technology offers low to medium power, a low to medium number of carriers per transmitter (i.e., 5 to 15 carriers), high reliability and low cost per sector, as well as easier engineering for outdoor use and low prime power consumption.

When considering a very large broadband block license, 500 to 1000 MHz of spectrum is available for up and downlinking. Assuming a roughly symmetric access traffic load, the deployed downlink bandwidth would be on the order of 250 to 500 MHz, depending on the specific spectral license. When considering 30 to 50 MHz of occupancy per RF carrier, a total of 5 to 12 carriers would need to be transmitted from each sector transmitter. This capacity requirement is reasonably well matched to the capacity of a state-of-the-art solid state transmitter based on the latest PHEMT MMIC power technology. Currently, this technology provides approximately 1 to 2 watts of compressed power. Employing balanced power stages in the design of the transmitter allows this to be practically increased to the 2 to 4 watts P_{1dB} range.

Further requirements can be established through

Modulation Scheme	SNR at Min Processable Signal	External Interference C/I	Allowable TX IM C/I	Resulting C/(N+I) in the receiver
QPSK	10	19	19	12
16QAM	16	25	25	18
64QAM	22	29	29	24

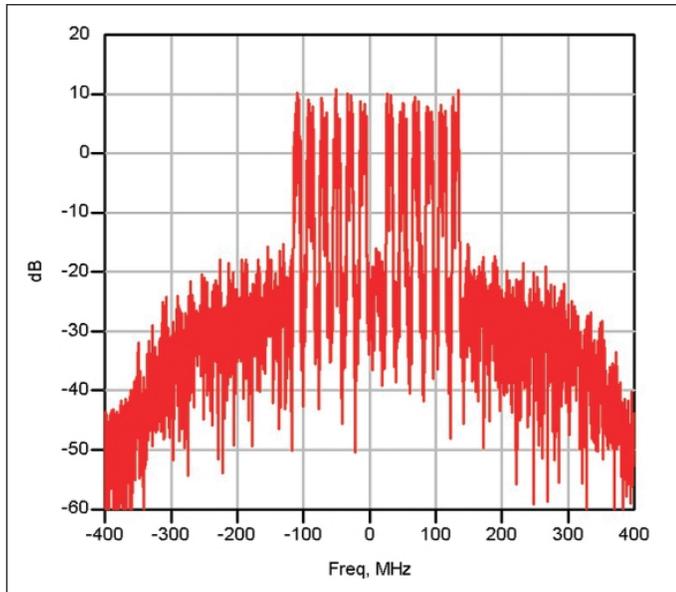
▲ **Table 2. Examples of noise and interference factors impacting received processing threshold.**

reviewing link budgeting analyses. Typically, several kilometer radius cells (3 to 5 km, depending on the rain region) with high-link availability (~99.995 percent) are required. Assuming a high gain sector antenna (~20 dBi) and high gain circular probably error (CPE) antennas (~36 dBi), a transmit power of ~17 dBm per carrier is required.

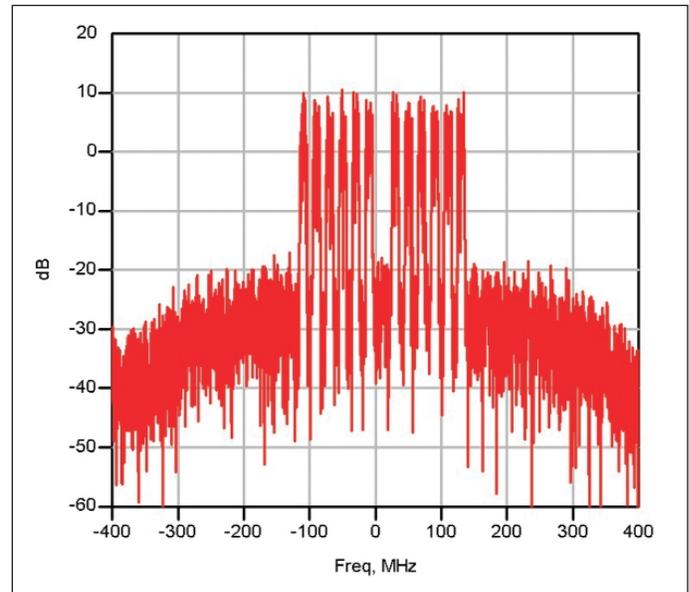
The back-off requirements of a multicarrier base station sector transmitter are shown in Table 1. This does not consider the needed intermodulation distortion performance. When a sector transmitter is driven towards compression, various nonlinearities begin to cause undesirable transmitter attributes, such as intermodulation distortion. The various RF carriers are supported by the transmitter mix in the transmitter and form spectral products. In a multicarrier scenario, these products can end up on top of the desired signals and are, therefore, not filterable. These products then effectively reduce the transmitted carrier-to-interference (C/I) ratio which the supported LMDS CPE receivers must be able to demodulate. The receivers are exposed to a number of elements that erode the basic received signal-to-noise (SNR) ratio, including intercell and intersector co-channel interference, adjacent channel interference, base station transmitter C/I and basic receiver thermal noise.

When considering various modulation schemes, degradations from various interference sources and the base station transmitter intermodulation can be treated as noise-like signals (in the broadband case) that add to the thermal noise floor, effectively reducing the receiver processing threshold. Table 2 shows some typical scenarios and how the transmitted C/I can contribute to overall sensitivity reductions in the CPE receivers that are being supported by a given multicarrier LMDS transmitter.

An example of the achievable transmitted waveform (without transmitter masking filters applied) is shown in Figure 2 (no linearization) and Figure 3 (with linearization). Shown is a low power DragonWave solid state sector transmitter handling 12 broadband QPSK modulated signals (~20 MHz BW). The technology employed in this transmitter allows it to produce ~20 dBm/carrier power and high-performance linearity with a P_{1dB} of only 2 watts. Figures 2 and 3 show the in-band intermodulation levels by omitting the center carrier so that the underlying IM product levels can be clearly seen. It is also possible to see the improvement provided by linearization of the sectorized transmitter. In the case with no linearization, the IM levels are 3 to 5 dB worse, making it suitable for QPSK only. The linearized unit is suitable for QPSK, 16QAM or 64QAM, making it more compatible with the latest overair MAC/PHY layers that support advanced efficiency enhancing features such as dynamic modulation selection (i.e., IEEE 802.16).



▲ **Figure 2. A typical LMDS sector transmitter output showing broadband carriers and associated intermodulation products (transmitter without linearization).**

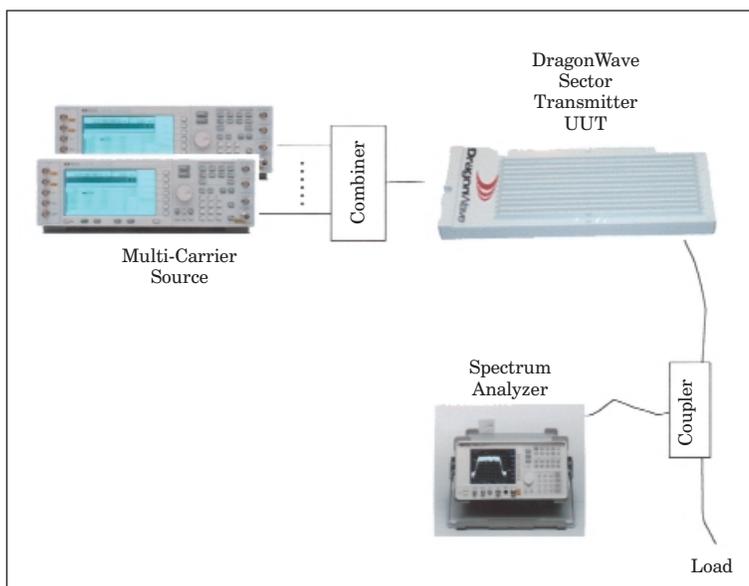


▲ **Figure 3. A typical LMDS sector transmitter output showing broadband carriers and associated intermodulation products (transmitter with linearization).**

Multicarrier test considerations

Testing the intermodulation performance of a multi-carrier LMDS transmitter is reasonably straight forward. These transmitter units are typically driven at low-frequency IFs (S-band or lower) where multicarrier generators are available or constructible using low cost sources (i.e., DDS boards). The output intermodulation results are readily gathered using a conventional spectrum analyzer. Figure 4 shows a typical test setup used for this type of testing.

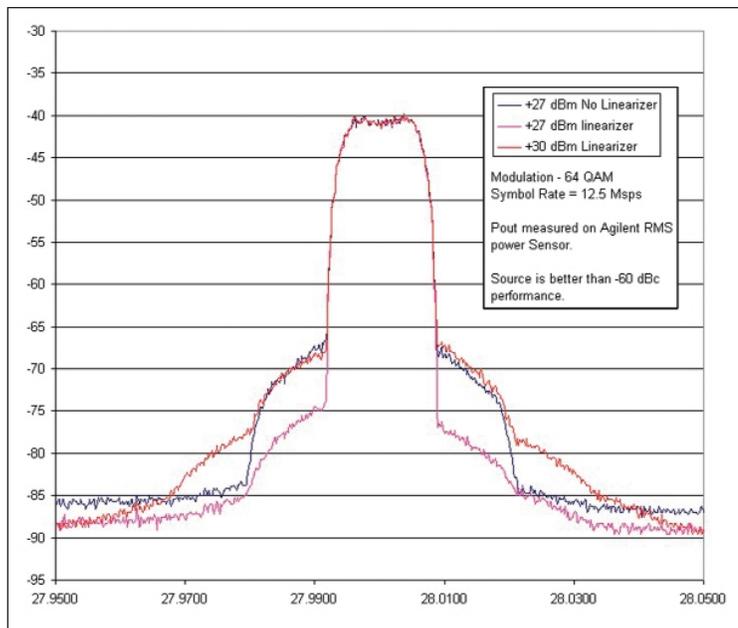
Several factors must be carefully considered during



▲ **Figure 4. Example of a test setup for multi-carrier solid state LMDS sector transmitter intermodulation testing.**

the setup of this test facility in order to avoid errors induced by the test setup itself:

- Individual carriers generated by the test source must be fully incoherent. The incoherent signals will then produce random intermodulation products which then add up incoherently. Ultimately, this produces lower average distortion products.
- The multicarrier test source must produce carrier sidebands that are well below the measured IM product levels (>20 dB) put out by the transmitter. If this is not the case, then there is a possibility that the test source is influencing the measured IM performance levels or even causing more products to be generated.
- The test source signals should be close replicas to the actual modulated data signals that the transmitter is expected to handle during actual operation (and during type-approval exercises). The IM levels and their spectral extend are highly dependent on the specific input signals driving the transmitter.
- Care must be taken to ensure that the spectrum analyzer is not contributing to the IM products it reports. Typically, it should be operated well into the linear region (i.e., 30 dB below compression, including effects of front end attenuators). Figure 4 shows the inclusion of a coupler, which reduces output signal levels from the transmitter well into the spectrum analyzers linear range. The coupler also ensures that the transmitter is optimally loaded.



▲ **Figure 5. Measured results of the transmitter prototype.**

- If the carriers are not evenly spaced in practice, they should be randomly spaced in testing as well. Random spacings and bandwidths will reduce overall IM product levels, since the IM spectral locations also become random, thereby reducing the effects of “stacking.”
- The “missing carrier” method of measuring the IM levels is fairly standard and shows the worst case levels. Care must be taken to accommodate the transmitters operating bandwidth. For example, the 12 carrier test results taken in Figure 2 and Figure 3 actually consume enough bandwidth for 13 carriers, since the center one is “missed” to allow measurement of the inband IM levels.

In order to verify the simulations, prototype units were built and tested. Results are shown in Figure 5.

Conclusion

Broadband LMDS transmitters are required in order to optimize base station rooftop equipment deployment, optimize base station costs and increase overall service revenues. Nonlinear distortion within these multi-carrier sector transmitters can be figured through the direct

measurement of intermodulation (IM) distortion products produced. Using simple techniques, this measurement can be easily undertaken when test setup pitfalls are avoided. ■

Author information

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