

# Synthesize and Build a Custom HDTV Antenna

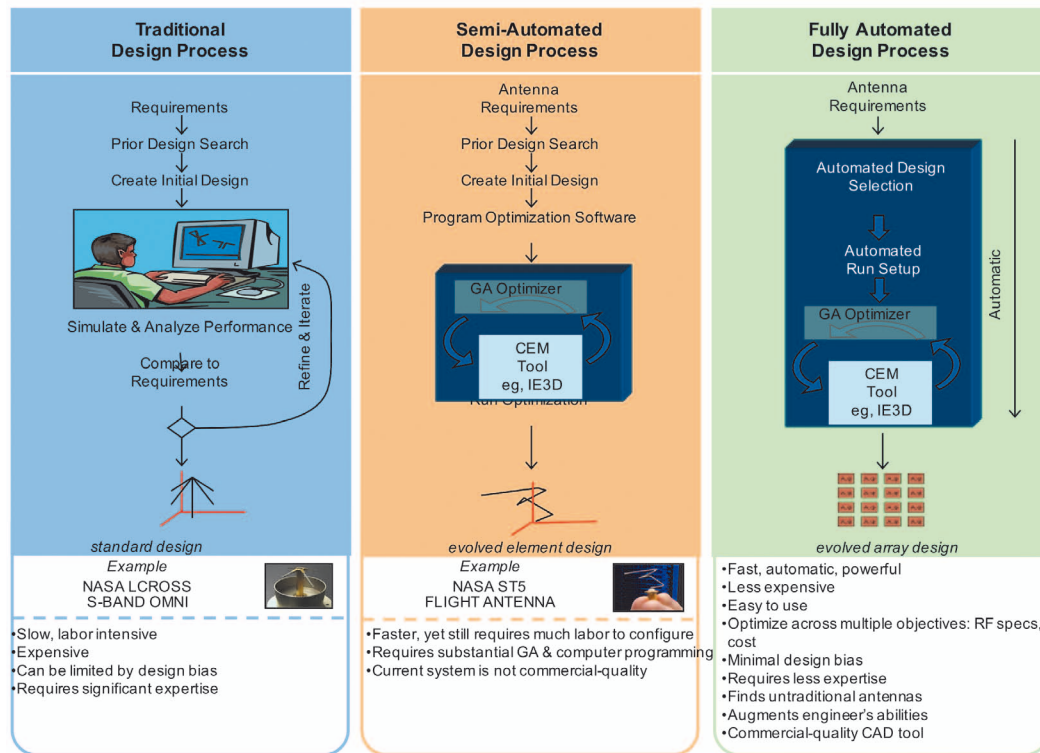


Figure 1: Evolution of antenna design process: traditional, semi-automated, and, finally, fully-automated design process

**This application example demonstrates how to use AntSyn software to design and build a customized high-definition TV (HDTV) antenna by generating a set of antenna specifications such as frequencies, bandwidth, and gain, for planar antennas such as Yagi and ultra-wideband dipoles.**

Next-generation wireless technology for applications including 5G, internet of things (IoT), aerospace radar, smart cars, wearables, and more requires antenna solutions that are optimized for high performance, low cost, and a small footprint. In addition to the design challenges of wireless technology, the demand for experienced antenna designers greatly exceeds the current supply, necessitating a design approach that is relatively fast and simple, yet enables engineers to meet demanding performance, cost, and size requirements.

## Traditional Design & AntSyn

In the traditional antenna design process, the engineer usually starts with books or models, deciding which antennas to try or not to try, and then goes into parameter sweeping and

tuning to optimize each chosen design type for the application of interest. This is a very time intensive and laborious process that requires significant exper-

tise of electromagnetic (EM) simulation and optimization of antennas.

In response to the need for a simple yet robust solution for designing wireless antennas, NI AWR software offers AntSyn antenna design and synthesis software that automates the process of designing and synthesizing antennas. Users do not have to know programming or optimization to use this tool and are able to make progress even with limited antenna knowledge. Figure 1 shows the evolution of antenna design processes from traditional, to limited synthesis, to the AntSyn system.

## HDTV Antennas

Most antennas in electronics products are now fully integrated within the application and not user accessible. HDTV is one of the few applications where consumers still have access to antenna components because televisions still have antenna connections to receive over-the-air signals.

There are many kinds of HDTV antennas on the market. World-wide channels include very-high

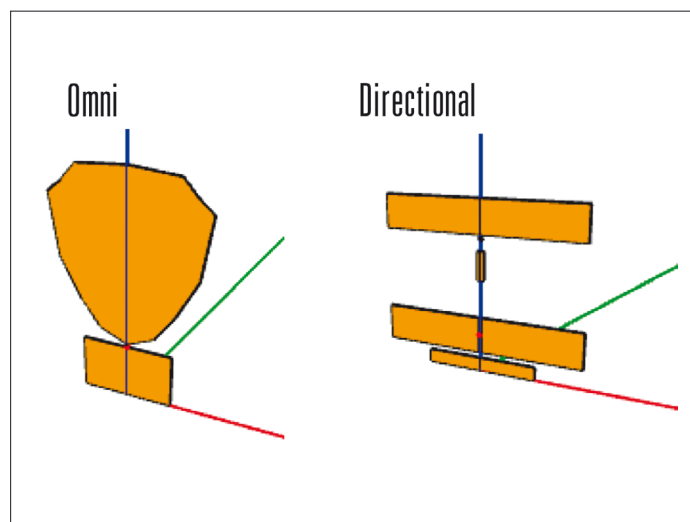


Figure 3: The two basic choices for HDTV antennas are omni antennas for use near many stations and directional antennas for use where stations are more distant, and the antenna can be oriented

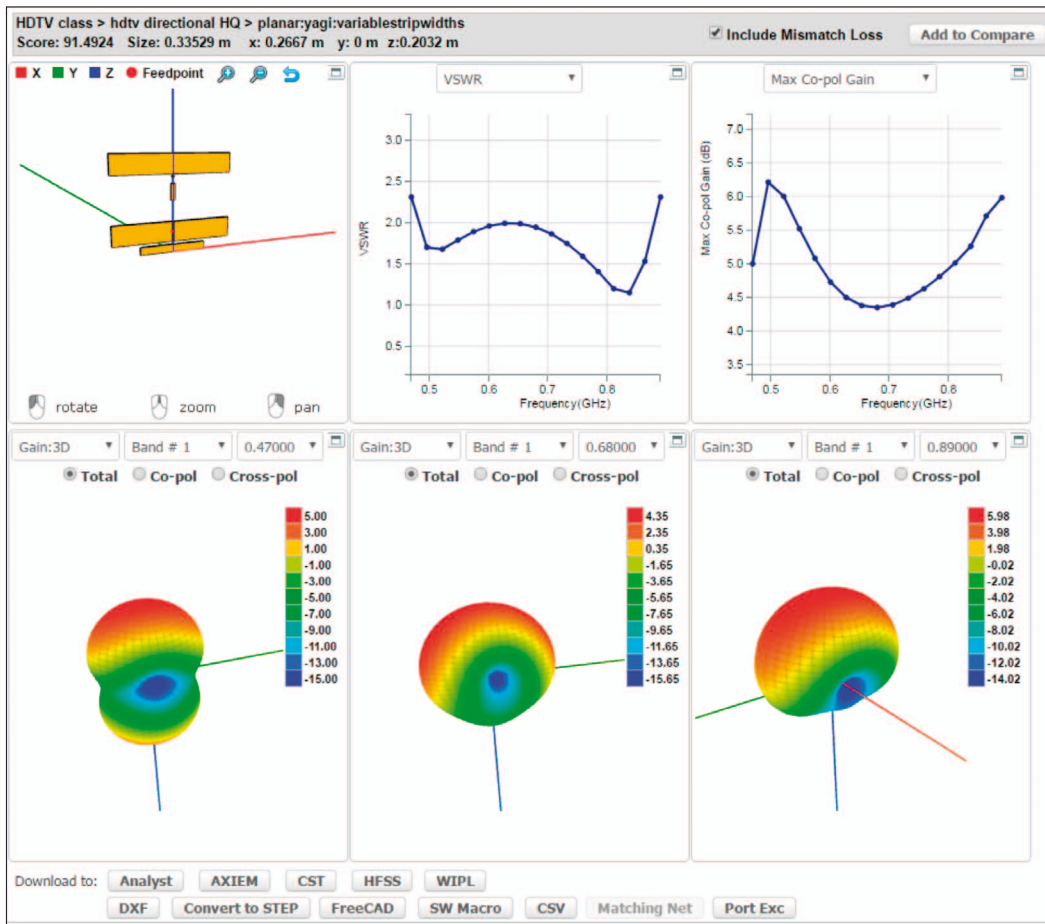


Figure 2: Highest gain and bandwidth, with this size covering the full UHF band (470...890 MHz) limits gain to 4...6 dB

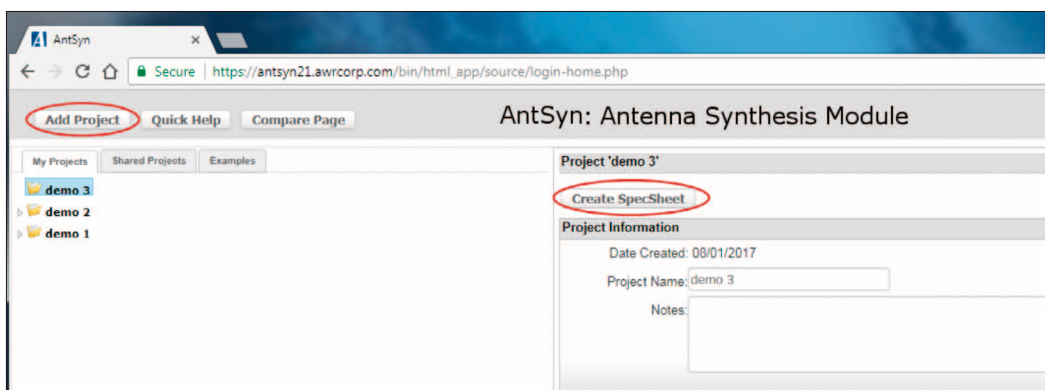


Figure 4: Buttons to create a new project and specsheet

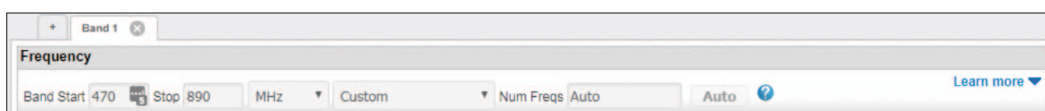


Figure 6: Setting band and frequency specs

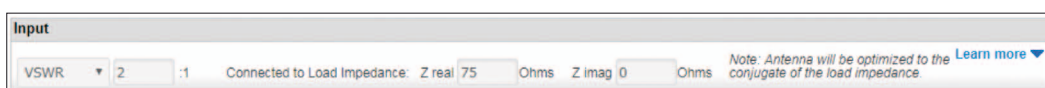


Figure 7: Setting impedance match

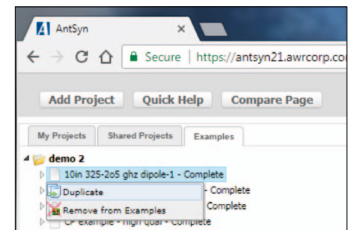


Figure 5: Duplicating an example specsheet

frequency (as low as 43 MHz) and ultra-high frequency (UHF). This particular application example is limited to the UHF band due to size limitations that were imposed for easy construction, but it is possible to expand this concept to VHF if one is willing to build larger antennas. Even with the size and shape limitations of this example it is still possible to cover the entire worldwide UHF band (470 to 890 MHz) with a single antenna that is smaller than a sheet of U.S. letter paper and has a gain of 4 to 6 dB, as shown in Figure 2 and described in more detail later.

There are two basic choices in HDTV antennas: omnidirectional antennas that are appropriate if there are many stations nearby such as in a city, and directional antennas with more gain that are potentially better if the stations are further apart and the antenna can be oriented to point at the origin of the signal (Figure 3). Frequencies covered would generally be the same for each type.

## Setting Specifications

AntSyn software enables the user to set a very wide range of specifications in the SpecSheet form. Users can set their own specifications or use a standard example provided by AntSyn software as a starting point. If a new project is needed, click the "New Project" button on the top left of the page and a new folder will be added to the project tree. To start a new SpecSheet, simply click on the "Create SpecSheet" button that appears when a project folder is selected, as shown in Figure 4.

Gain Pattern

[Learn more](#)

Elevation: 0 to +180

Azimuth: -180 to +180

- ☒ Gain vs Elevation Angle
- ☐ Gain vs Azimuth Angle
- ☐ Gain and Beamwidth (Elevation)
- ☐ Gain and Beamwidth (Azimuth)

At this elevation:  
deg       $\approx$       =       $\leq$       dBi

<input checked="" type="radio"/> 180	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	6	<input type="button" value="GO"/>
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="button" value="GO"/>
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Coverage in Azimuth

☐ Rotationally symmetric around the Z axis

This spec covers 0 to 0 deg in Azimuth

(Allowed range: -180 to +180)

- ☒ Includes all losses
- ☐ Includes dielectric loss (perfect match)
- ☐ No loss (directivity)

Elevation view

3D gain angle visualization

Gain: ■ greater ■ equal ■ less

**Figure 8: Setting gain spec for directional case – skipped for omni case**

To use an example SpecSheet, right click on the specification of interest and select “duplicate.”

Follow the prompts to put the spec into the right project folder (Figure 5).

The SpecSheet is designed so that the user can usually start at the top of the form and work

down the sheet to the bottom. The first specs to be chosen are the bands and frequencies, which are fundamental to almost every antenna, shown in Figure 6.

In this case, a start frequency of 470 MHz and a stop frequency of 890 MHz cover the complete range of UHF HDTV frequencies worldwide, including the U.S. (470 to 698 MHz), Canada (470 to 806 MHz), Korea/Taiwan/Japan (470 to 890 MHz), UK/Ireland/Hong Kong (470 to 862 MHz), Western Europe/most of Asia and Africa (470 to 861 MHz), France/Eastern Europe/Former Soviet Union (470 to 862 MHz), and Australia (527 to 820 MHz).

The specification for the impedance match is next. Standing-wave ratio (SWR) or S11 can be set (among other things), along with the desired impedance. The impedance of a standard TV cable is 75 Ohms, so that is what has been set in Figure 7.

The next antenna property to address is gain. For the omnidirectional case, the gain does not need to be set because the antennas to be selected are omni by

## Geometry and Environment

Antenna axis points toward ☐ X ☒ Z

Dimension units:  [?](#)

☒ Constrain Antenna Geometry  
(Applies to full antenna unless separate constraints are applied to Built-in Ground)

Max Shape:  X  Y  Z  in

☐ Apply Separate Constraints to Built-in Ground

Built-in Ground Size Max

Shape:  X  Y  Z  in

Built-in Ground Size Min

Shape:  X  Y  Z  in

Location on Ground (if applicable):  [?](#)

Ground Type (advanced):

☐ Infinite Ground

☐ Mast/Standoff Min  Max  in

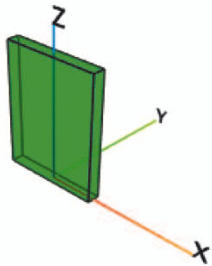
☐ Use dielectric, if applicable

Dielectric constant:  Loss tangent:

☐ Only design antennas that use a dielectric substrate

### Geometry Constraints

☒ Antenna
 ☒ Built-in Ground
 ☐ Infinite Ground

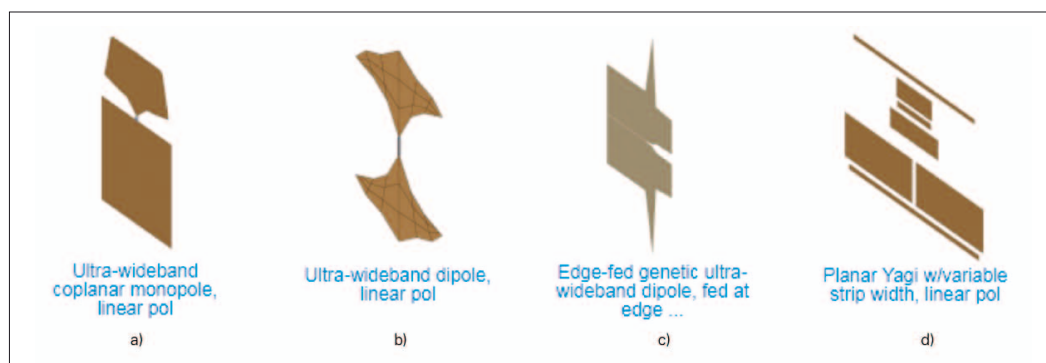


Built-in Ground Size: ☒ View Max ☐ View Min

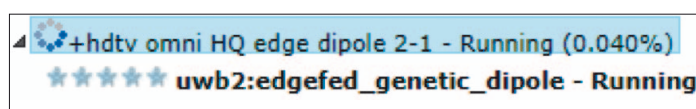
Mast/Standoff Height: ☒ View Max ☐ View Min

**Figure 9: Setting size limits**





**Figure 10: Antennas used for this example: a) standard UWB dipole, b) UWB edge-fed dipole, c) UWB coplanar monopole, d) planar Yagi with variable-width strips**



**Figure 11: SpecSheet run in progress.**

nature and fairly small. By not having a gain specification, the antenna will run a bit faster. If this assumption turned out to be incorrect, or if some other error were made to the SpecSheet, the user would simply need to duplicate the specification from the right-click menu, add a gain spec, and re-run the antenna.

With the directional case there are some gain requirements built into the SpecSheet (Figure 8). None of the polarization or other advanced features for gain specification are being used in this example and the gain is actually specified for the downward direction, this is explained in the results section.

One of the key areas is the shape or overall limit on the form factor. To make these antennas easy to construct, they were all limited to 8" (203 mm) in width and 10.5" (267 mm) in height, with a planar form factor (Figure 9). This limit was chosen because the design was printed to a standard U.S. letter size piece of paper to be used as a template to cut out the antenna on a single-sided foil-clad board.

## Selecting Antenna Types

There are 240 antenna types currently available in the AntSyn library as a starting point for

the synthesis/optimizer, and if the user does not select any, the AntSyn tool will select antennas automatically based on what could work with the given specifications. In this example, four different types of antennas were

selected: three versions of a planar ultra-wideband (UWB) omni antenna and a directional Yagi antenna (Figure 10).

These antennas are described in more detail in the Results section.

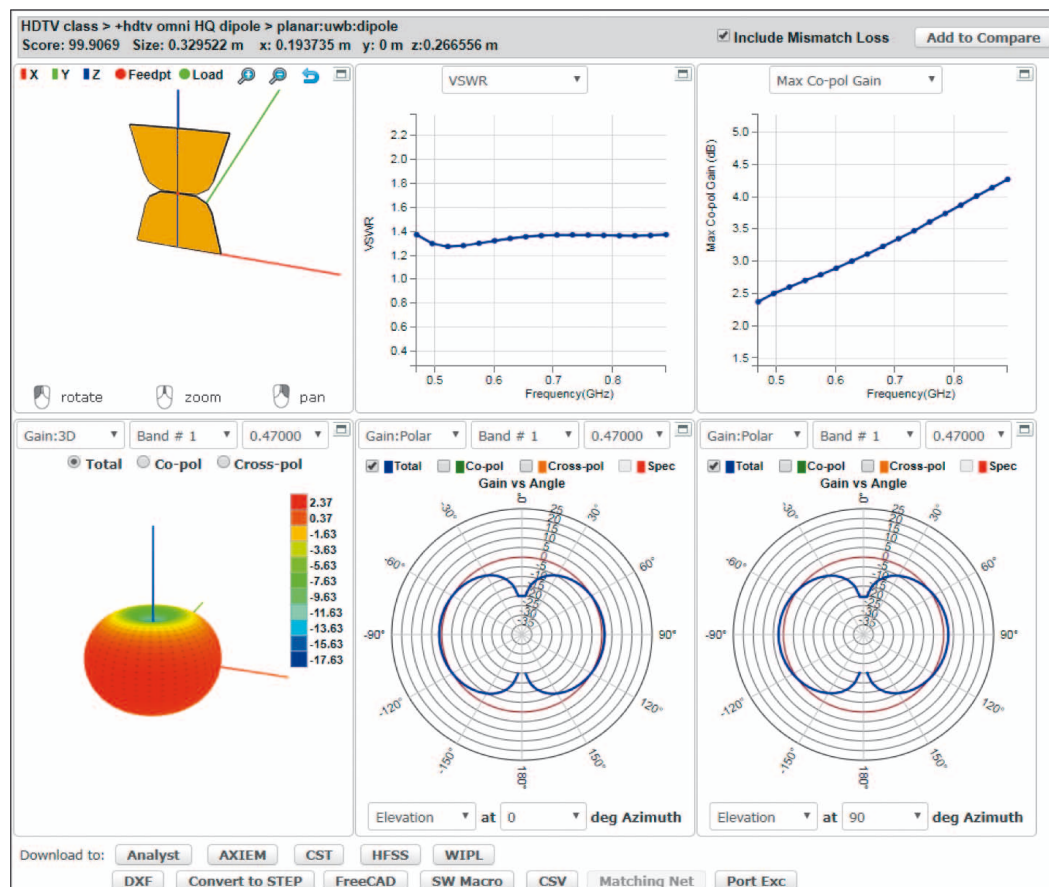
## Running AntSyn Software

Once the specs have been added as desired, the quality level and run are set. For this ex-

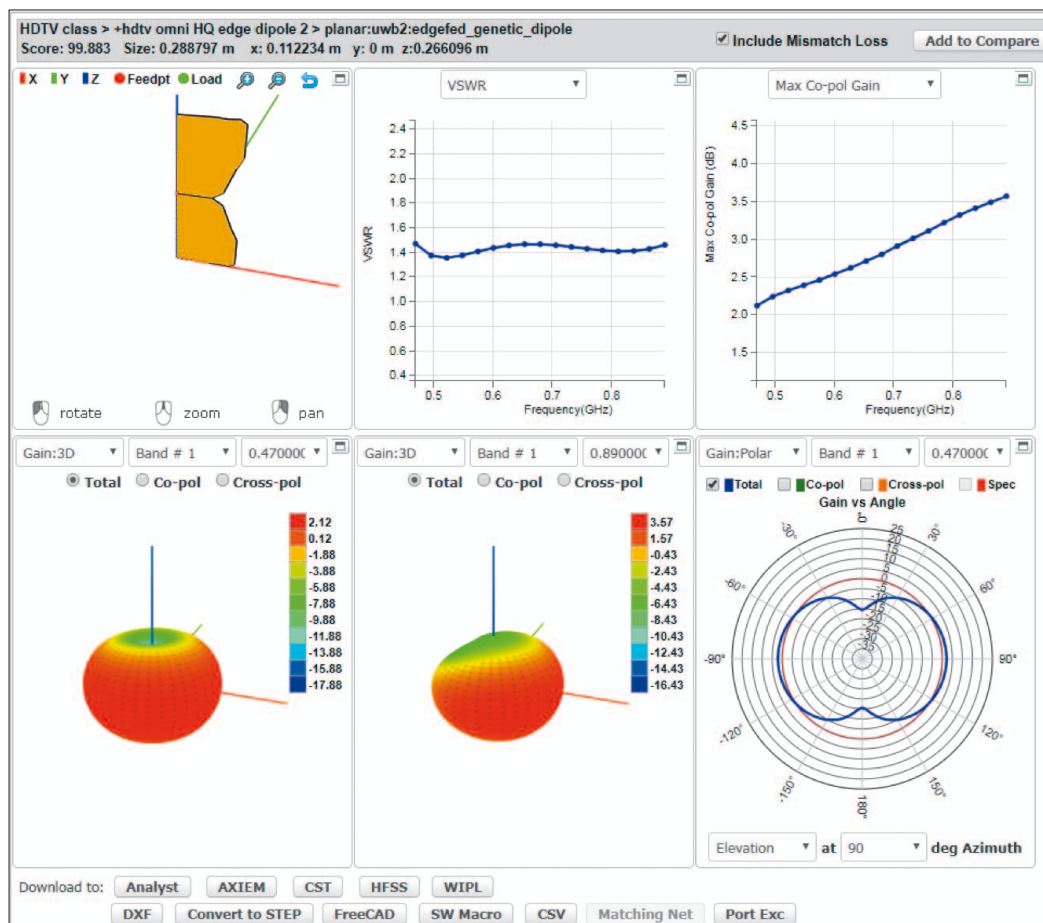
ample, omni antennas run best at medium quality and should finish in less than five minutes. Directional antennas take much longer to run (low quality about 15 minutes, medium quality about 40 minutes, high quality 3 to 4.5 hours). Medium quality has been selected here because it only takes 1 to 10 minutes to complete. If it is desired to see the progress of a run while it is ongoing, keep clicking on the antenna name and the latest results will be shown (Figure 11).

## Results

The results for the standard UWB omnidirectional antenna, which has a pattern that looks omnidirectional across the entire frequency range, are shown in Figure 12. This antenna would be used if the antenna is near strong TV stations and forward gain is not needed to pick up the signals. Figure 13 shows an antenna that is fed on its edge, which has the interesting characteristic of not requiring the



**Figure 12: Standard UWB dipole results**



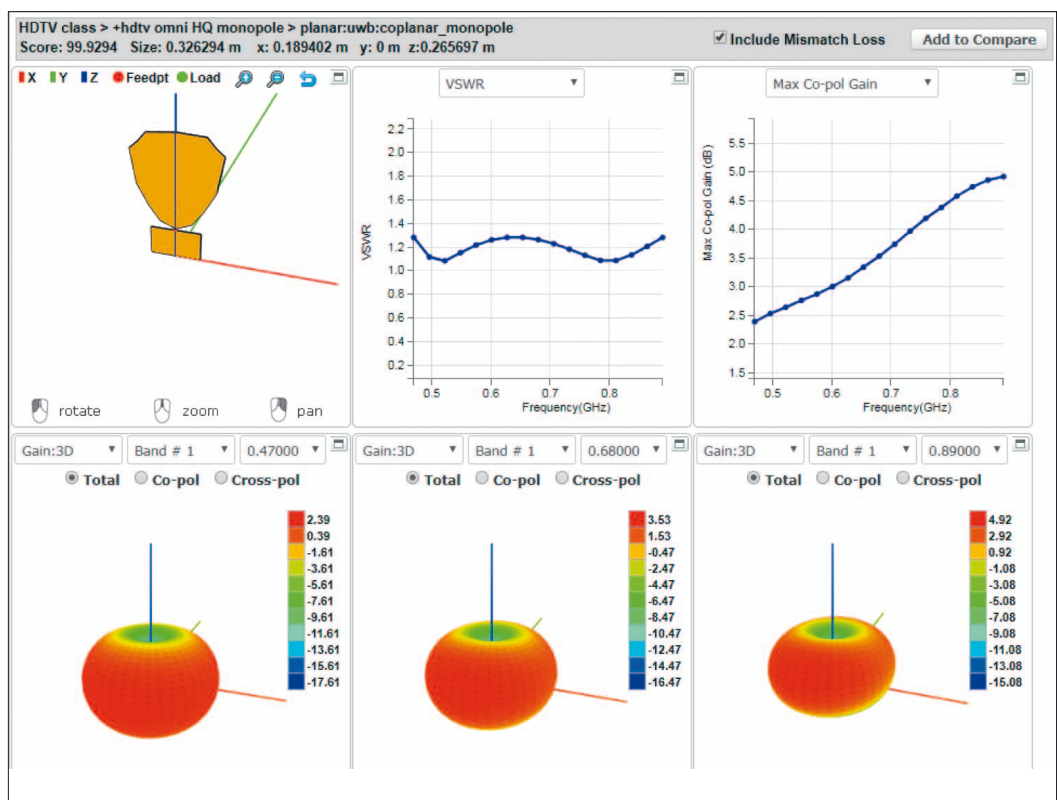
**Figure 13: UWB edge-fed dipole results**

feed cable to cross the antenna; it can just be put on the edge of the card to save space.

Figure 14 shows a UWB coplanar monopole antenna with a small side and a large side. It is still an omnidirectional pattern, regardless of the frequency. The gain changes a bit with frequency, but it is still basically omnidirectional. This could be useful if RF equipment such as an amplifier would be integrated on the large side as it provides a larger surface for mounting.

The result for the directional antenna optimized under these size constraints was shown in Figure 2, and is repeated in Figure 15a), along with a photo of a prototype in Figure 15b).

This antenna has gain that is pointed backwards compared to a typical Yagi. The antenna Z axis is actually turned upside down and pointed toward the bottom of the diagrams for the antenna rendering and the pat-



**Figure 14: UWB coplanar monopole results**

terns. It was noted during synthesis that higher gains were resulting toward the -Z direction, so the spec was changed to take advantage of this behavior. This shows the ability of the AntSyn tool to discover new ways of configuring typical antennas to achieve unusual results.

A typical Yagi antenna, starting at the origin and working along the +Z axis, has a single reflector element, then the driven element, then a number of director elements that help the energy to flow from the driven element in the +Z direction. It is also usually narrowband and would not be able to cover the full UHF band. The AntSyn result is quite unusual in how it solves the requested specifications. The software turned the reflector into a so-called sleeve element for the fed dipole, which extended the frequency range to the full 470 to 900 MHz. It also turned the director elements into a reflector element to increase gain. The result is that more gain is pointed in one direction, which is what we wanted, and the antenna works across the full UHF band.



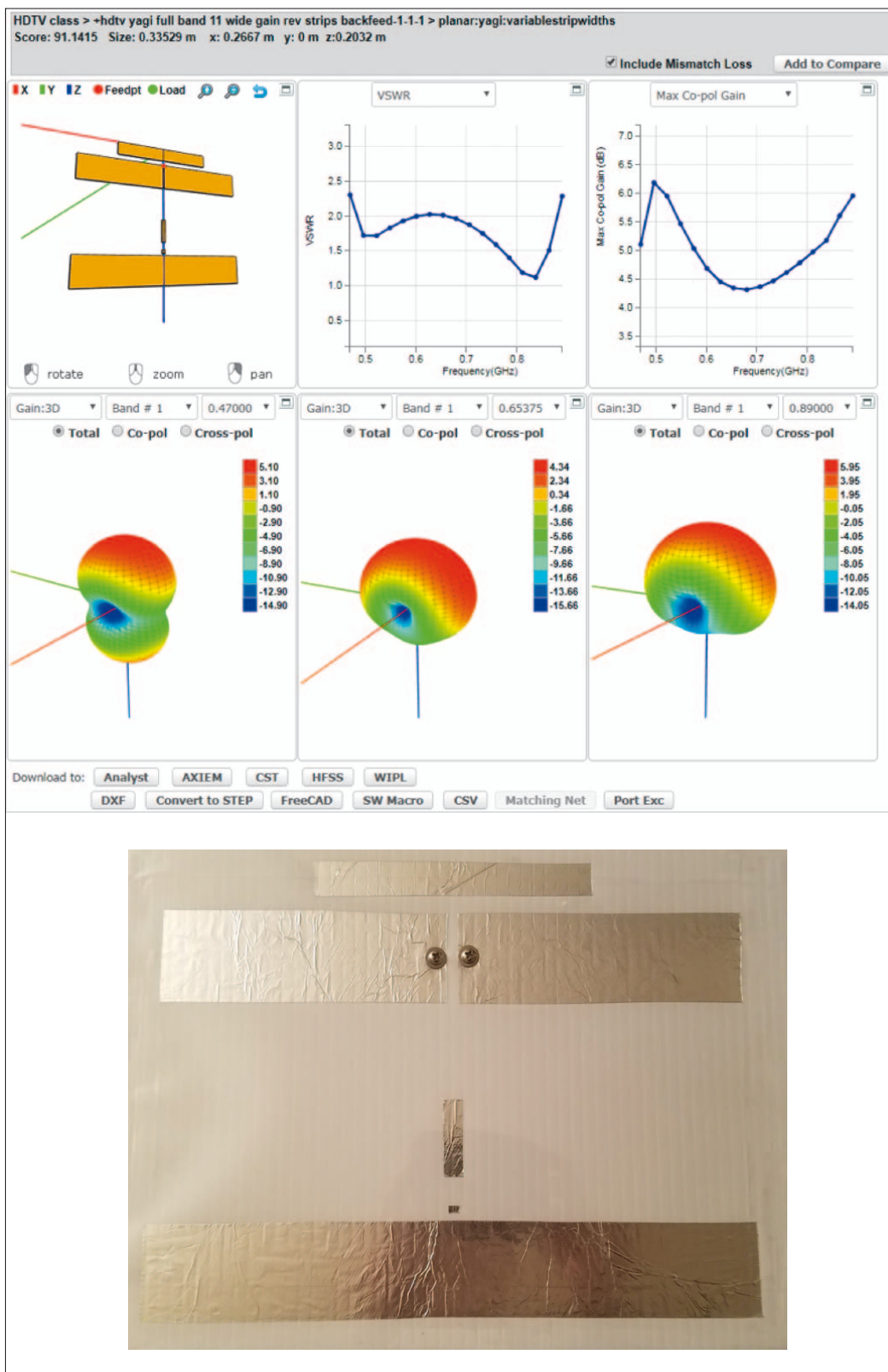


Figure 15: Directional Yagi antenna a) AntSyn results, b) photo of a prototype

## Build and Test

When the optimization run is finished, the new antenna design is ready to build. To do so, the user can download the drawing

(DXF file) using the DXF button at the bottom of the results page and print it to scale using a program like AutoCAD's DWG TrueView. With a printout of the design, the following steps can

be followed to manufacture a prototype for testing:

1. Make a foil-covered board. Use spray adhesive to make the surface of a foam or coroplast

board sticky and unroll aluminum foil across the board. Cut off the excess foil and smooth it to the board using a plastic paint or putty spreader.

2. Tape the printed page to a foil-covered board.

3. Use a sharp utility knife to cut out the pattern. Only cut the paper and foil, do not cut too deeply into the board which will hold the antenna together.

4. Carefully peel off the excess foil.

5. Bring the panel to use to drill the holes in the board for the cable.

6. Screw down the leads from a standard TV coaxial cable, with the center conductor on one side of the feed point and the outer jacket on the other side. Note that screws or conductive metal tape will be needed to attach the leads, as solder does not work on aluminum foil.

7. Cover with a clear plastic sheet to protect the foil, if desired, such as a transparency slide.

8. Write any information necessary on the antenna (such as frequency, gain).

9. Test using, for instance, a network analyzer, HDTV receiver, or spectrum analyzer.

## Conclusion

This application example has demonstrated the ability of the AntSyn antenna synthesis tool to quickly and easily generate an HDTV antenna design from specifications for performance requirements, size, and material constraints input by the designer. In this simple HDTV antenna example, AntSyn software synthesized a unique Yagi-type antenna that was easily fabricated and shown to provide the required performance in the constrained form factor.

A related video demonstrating this design example can be found at [vimeo.com/230666087](https://vimeo.com/230666087).

Special thanks to Derek Linden, AWR Group, NI, for his contributions to this application note. ◀